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HELD AT PHILADELPHIA

FOR

PROMOTING USEFUL KNOWLEDGE

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IDENTICAL ELECTRICAL NETWORKS IN SERIES.

BY A. E. KENNELLY.

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STATEMENT OF THE PROBLEM.

A dissymmetrical electrical network of any kind, such as the simple alternating current net indicated diagrammatically in Fig. 1, is known to be reducible at any one frequency and with respect to

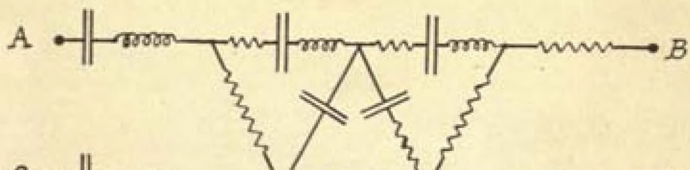

FIG. 1.

the input and output terminals AG, BH, to a certain equivalent T as in Fig. 2, or to a certain equivalent π as in Fig. 3. The T and the π are, in general, dissymmetrical. Any such net is completely defined, for the frequency and the two pairs of terminals considered, by three constants,[1] a hyperbolic angle θ, a geomean surge impedance z_{ab} and an inequality ratio q. These three characteristics are, in general, complex quantities.

Suppose now that we have a plurality of such networks identical

[1] Bibliography 14.

in all respects, and that it is desired to connect them in simple series. It is required to find the properties and characteristics of the resulting network so produced.

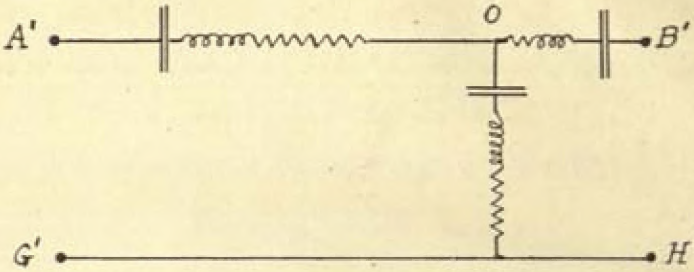

FIG. 2.

The problem may be attacked by replacing the nets by their equivalent T's or π's, and connecting these in the desired series arrangements.

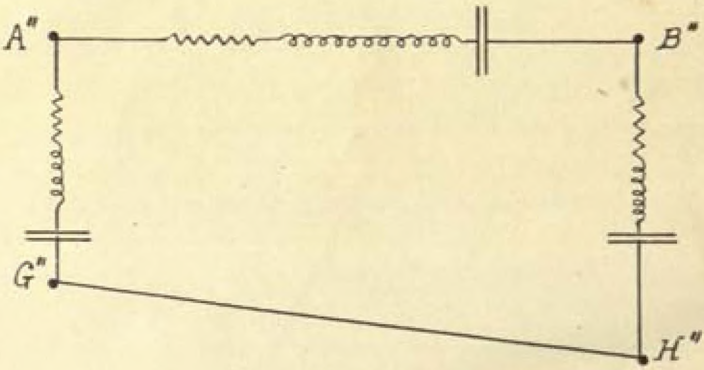

FIG. 3.

Figure 4 presents a direct-current network of twelve resistances, which with respect to the pairs of terminals $A'\ G'$ and $B'\ H'$, has an angle of $\theta = 0.75178$ hyperbolic radian, a geomean surge impedance $z_{ab} = 4123.11$ ohms, and an inequality ratio $q = 0.92582$. The equivalent T of this network is shown in Fig. 5, and the equivalent π in Fig. 6. All three systems have the same θ, q and z_{ab}. The net of Fig. 4 may serve as a convenient example for study, because of the simple numerical values of the resistances in its T and π.

Two Methods of Series Connection.

When two like nets are connected in series, using corresponding pairs of terminals on each, there are two methods of connection which may be used. One, which may be called the *forward* method,

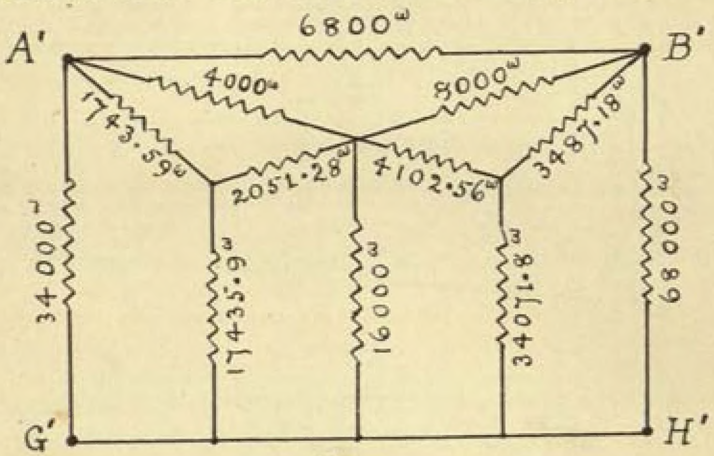

FIG. 4.

indicated in Fig. 7, joins unlike pairs, B to A' and H to G'. The other, indicated in Figs. 8 and 9, may be called the *back-to-back* method, and comprises two varieties of connecting like pairs. In

$$\theta = 0.75178 \qquad q = 0.92582 \qquad z_{ab} = 4123.11^{\omega}$$

$$z_{oa} = 3817.26^{\omega} \qquad z_{ob} = 4453.46^{\omega}$$

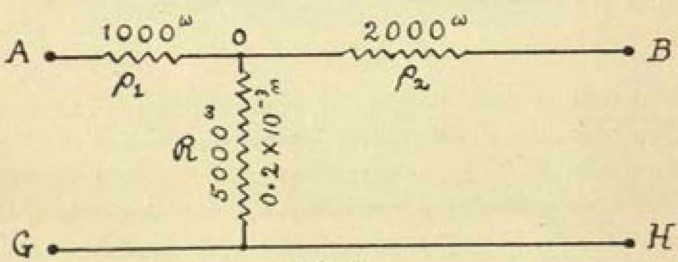

FIG. 5.

Fig. 8, the two nets are connected with the B B' terminals back to back; while in Fig. 9, they are connected with their A A' terminals back to back. These may be called back-to-back-B and back-to-back-A connections respectively.

Two Nets in Back-to-Back-B Series Connection.

Figure 10 shows the equivalent T of the two identical dissymmetrical nets of Figs. 4 and 8. This T has terminals a, g, at one end and a', g' at the other. It is symmetrical. That is, its $q = 1$. Its angle Θ is twice the angle θ of either component. Its surge

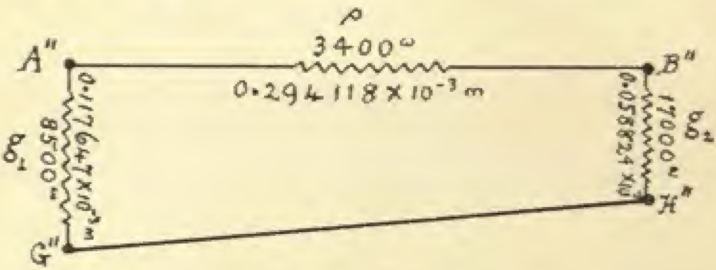

Fig. 6.

impedance z_o is equal to the surge impedance z_{oa} of either component of Fig. 5, as measured from the A pair of terminals. For the continuous-current case represented in Fig. 5, $\theta = 0.75178$ hyperbolic radian, R_{af} or the resistance of the net found at AG terminals with BH' open, is 6000 ohms, and R_{ag}, the corresponding resistance

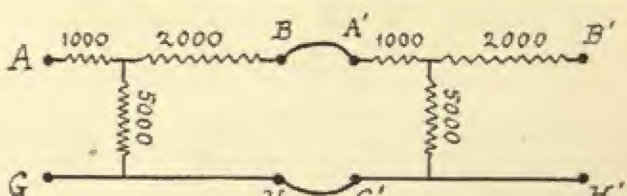

Fig. 7.

with terminals BH' shorted is 2428.57 ohms. The root ratio $\sqrt{R_{ag}/R_{af}} = \tanh \theta = 0.636209$, which determines θ. The root product $\sqrt{R_{af}R_{ag}} = z_{oa} = 3817.26$ ohms. Similarly, testing from the BH terminals, $R_{bf} = 7000$ ohms, $R_{bg} = 2833.33$ ohms, the root ratio $\sqrt{R_{bg}/R_{bf}} = 0.636209$, and the root product $\sqrt{R_{bf} \cdot R_{bg}} = z_{ob} = 4453.46$ ohms. The root product of the two surge impedances $z_{oa} = \sqrt{z_{oa} \cdot z_{ob}} = 4123.11$ ohms, and their root ratio $\sqrt{z_{oa}/z_{ob}} = q = 0.92582$. Taking now the double-net back-to-back-B system of Figs 8 and 10, the angle $\Theta = 2\theta = 1.50357$ hyps. $q = 1$, and $z_o =$

$z_{oa} = 3817.26$ ohms. These results may be proved either algebraically or by the merging of the two equivalent T's of Fig. 8.

Two Nets in Back-to-Back-*A* Series Connection.

The two networks being connected as in Fig. 9, the resultant equivalent T is shown in Fig. 11. It is symmetrical. $\Theta = 2\theta$ as before, $q = 1$ and $z_o = z_{ob} = 4453.46$. There is only one surge impedance for the dual system, obtainable from measurements either at b or at b', and it is equal to the surge impedance z_{ob}, obtained from the B or B' ends of the component separate nets.

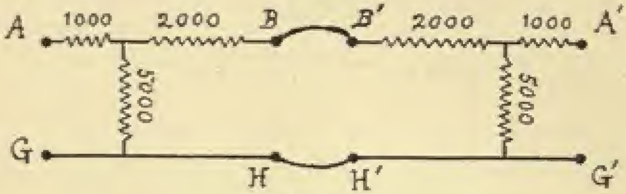

Fig. 8.

We may conclude, therefore, that when two dissymmetrical nets are connected back to back, the resulting system is symmetrical, has its angle Θ equal to the sum 2θ of the angles of the two component nets, and a surge impedance z_o equal to that obtained from the corresponding ends of the component nets.

N Pairs of Nets, Each Pair Either in Back-to-Back-*A* or Back-to-Back-*B* Connection.

If we consider two pairs of identical nets connected in series, each pair consisting of two dissymmetrical nets in permanent back-to-back-A connection; then from the deduction of the last paragraph, each pair is a symmetrical net, and each pair has the same angle Θ

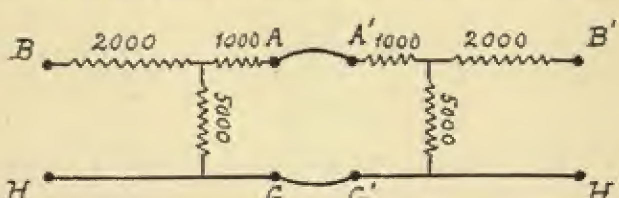

Fig. 9.

and the same surge impedance z_{ob}. Consequently the resultant net formed by the two pairs in series is symmetrical. Its angle will be 2Θ or 4θ, and its surge impedance will be z_{ob}.

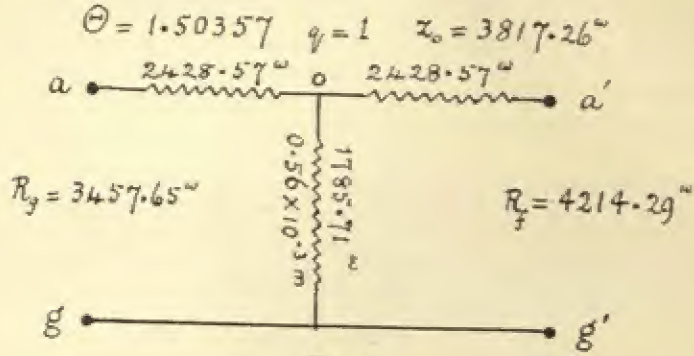

Fig. 10.

Similarly, if we have the component nets of each pair in permanent back-to-back-B connection, each pair will be a symmetrical net with angle 2Θ and with surge impedance z_{oa}.

It will thus be evident that if we place in series N pairs each in back-to-back-A connection, the resultant net is virtually an ordinary symmetrical artificial line of N symmetrical sections. The total angle of the line will be $N\Theta$, and its surge impedance will be z_{ob}.

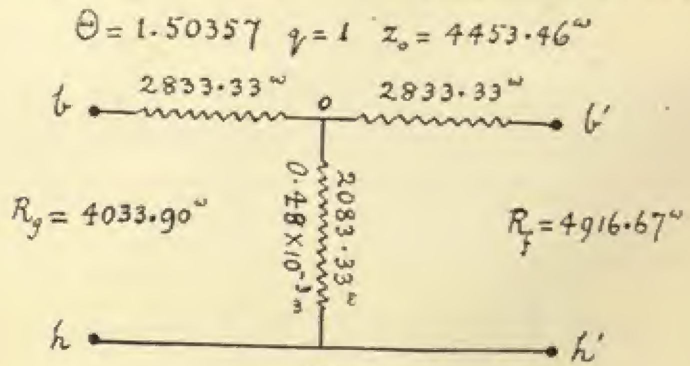

Fig. 11.

If the N pairs are all arranged of θ-sections in back-to-back-B connection, the resultant series net will have a total angle of $N\Theta$ and a surge impedance of z_{oa}.

Two Nets in Forward Connection.

If two identical and dissymmetrical nets are connected in forward series as in Fig. 7, each will have the same θ, q and z_{ab}. The resultant net, whose T may be represented in Fig. 12, will in general, be dissymmetrical; but its geomean surge impedance z_{ab} will always be the same as that of the components. Moreover, the difference between the impedances of the two resultant arms, a, o,

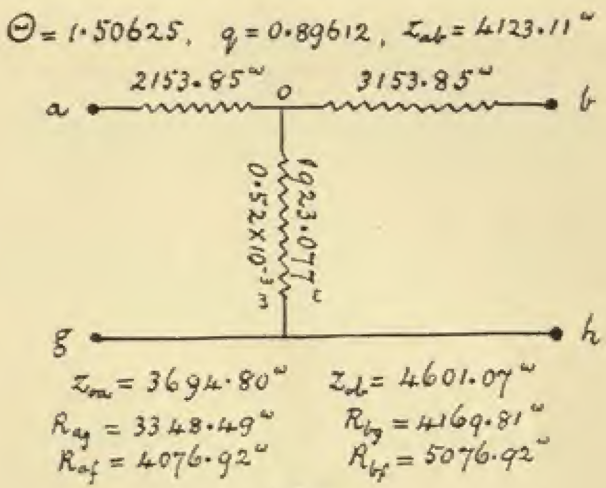

Fig. 12.

and o, b, in Fig. 12, will always be the same as the difference between the impedances of the component T arms AO and OB, or $A'O$ and OB', of Figs. 5 or 7. The angle Θ of the resultant net, will not, in general, be equal to the sum 2θ of the component network angles, nor will the inequality factor q of the resultant net be equal to that of the components.

The relations are

$$\sinh \Theta = \left(q + \frac{1}{q}\right) \sinh \theta \cosh \theta \quad \text{numeric } \angle \quad (1)$$

and

$$q' = \sqrt{\frac{(q^2 + 1)\cosh^2\theta - 1}{(1/q^2 + 1)\cosh^2\theta - 1}} \quad \text{numeric } \angle \quad (2)$$

when q is the inequality factor of the component nets, and q' is that of the resultant net.

The value of the pillar leak admittance in Fig. 12 for forward connection is the arithmetical mean of those in Figs. 10 and 11 for back-to-back connection.

Two Alternating-Current Nets in Forward Series.

Figures 15–18 illustrate the application of the same principles and formulas to alternating-current nets. Fig. 15 shows the T, and

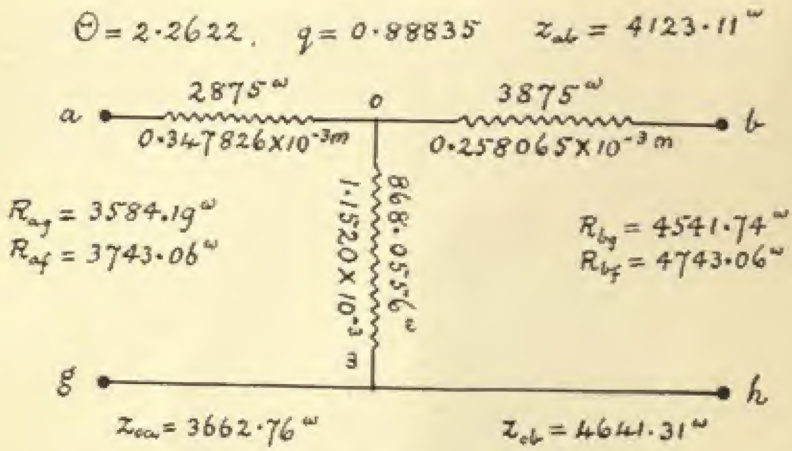

Fig. 13.

Fig. 16 the π, of a particular net at a certain frequency, and with respect to the pairs of terminals AG and BH. Two of these nets are then connected in forward series. Fig. 17 shows the resultant T, and Fig. 18 the resultant π, of the resultant net. It may be seen that the surge impedance z_{ab} remains constant at $4113.26 \measuredangle 9°29'7''$ ohms throughout the series. Also, the difference between the arms of the component and resultant T's is the same; viz. $1000-j\,1500$ ohms. Moreover, the difference between the admittances between the pillar leaks of the component and resultant π's is the same; namely $(-0.084716+j\,0.064629)\,10^{-3}$ mho. Charts or Tables of complex hyperbolic functions[3] are advantageously used in the solution of such alternating-current cases.

[3] Bibliography 12.

More than Two Networks in Forward Series.

Figure 13 shows the equivalent T of three nets identical to Fig. 4, in forward series connection, and Fig. 14 shows the corresponding equivalent T of four such nets in like connection. In each case it

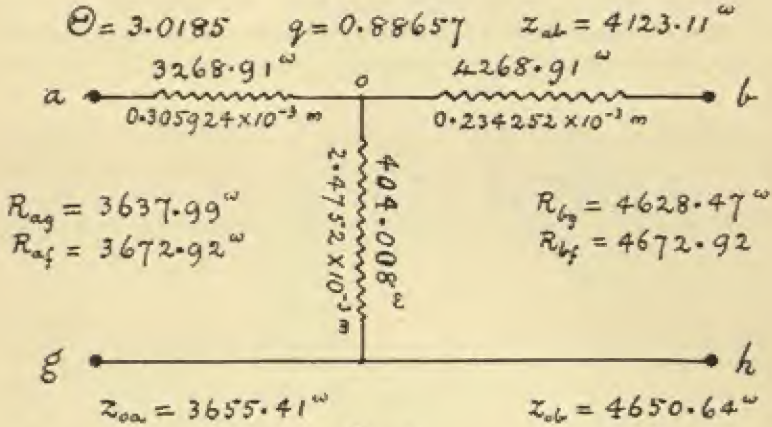

Fig. 14.

will be seen that the geomean surge impedance $z_{ab} = 4123.11$, is the same as that of the component net (Figs. 4 and 5); also that the difference between the arm impedances ao and bo of the T, is equal to that found in the T of Fig. 4. These properties continue to hold

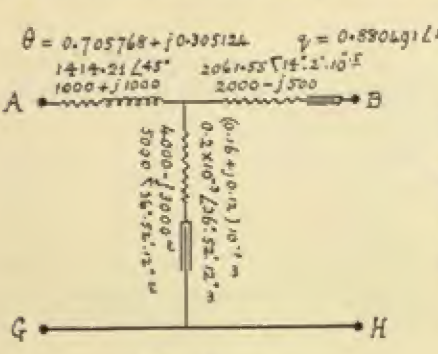

Fig. 15.

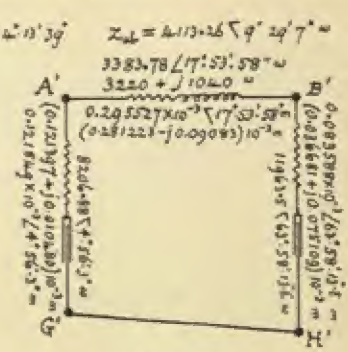

Fig. 16.

for any number of identical nets in forward series connection, and the reasons for them will be evident when the general artificial line is discussed.

Forward Series Connection of Identical Nets Computed by Position Angles.

It is always possible to deal with a forward series of identical nets by the method of position angles; although the plan is here ordinarily inconvenient and laborious. Figure 19 shows four nets so connected, each being the equivalent of those in Figs. 4, 5 and 6. The *EH* end terminals of the system being grounded, the fourth net

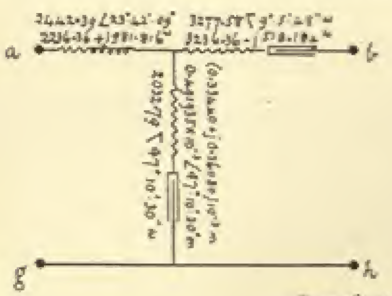

Fig. 17.

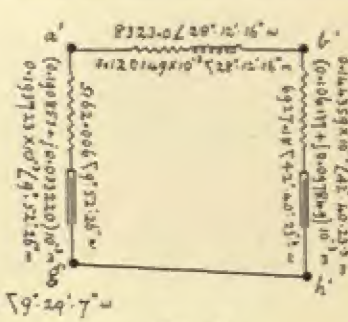

Fig. 18.

DE forms a terminal load of σ ohms $\angle$ at the terminal *D* of the system *ABCD*. The angle subtended by this load is

$$\delta_D = \tanh^{-1}\left(\frac{\sigma}{z_{ob}}\right) \qquad \text{hyps } \angle, \quad (3)$$

where

$$\sigma = z_{oa} \tanh \theta \qquad \text{ohms } \angle. \quad (4)$$

In the case considered, the z_{oa} of the last section is 3817.26. The z_{ob} of the third section terminating at *D* is 4453.46; so that

$$\delta_D = \tanh^{-1}\left(\frac{3817.26}{4453.46} \times 0.63621\right) = \tanh^{-1} 0.54532 = 0.61170 \text{ hyp.}$$

This position angle is marked at *D* in Fig. 19. The position angles at *C* and *B* are found successively in like manner. In order then to find the received current and potential at *B* under the application of say 100 volts at *A*, we may use the formulas

$$I_B = q\, I_A \left(\frac{\cosh \delta_B}{\cosh \delta_A}\right) \qquad \text{amperes } \angle, \quad (5)$$

and

$$E_B = \frac{E_A}{q}\left(\frac{\sinh \delta_B}{\sinh \delta_A}\right) \qquad \text{volts } \angle. \quad (6)$$

We then proceed to find the current and voltage at C by a repetition of the process, and so on until the end E is reached, where the current is 2.376 milliamperes and the voltage is zero.

Figure 20, shows the conditions at the two ultimate pairs of terminals a, g and e, h of the system, when the fourfold net is shorted at e, h and 100 volts is applied at a, g. The results are in agreement with those of the detailed system in Fig. 19. The single resultant T

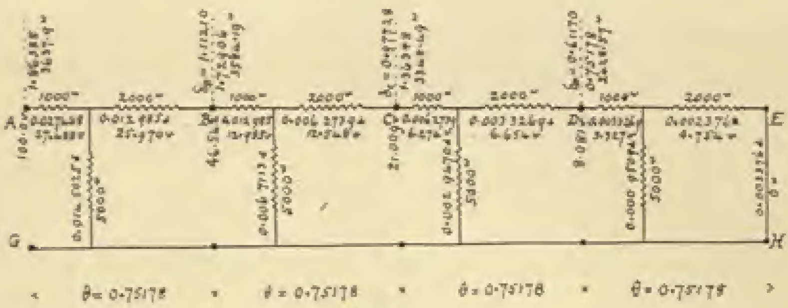

FIG. 19.

of Fig. 20 is much simpler than the fourfold T of Fig. 19, if we are interested only in the conditions at the two ultimate pairs of terminals. Nevertheless, there does not seem to be a simple general position-angle formula for arriving at the resultant T of Fig. 20, except by the measurements R_{ag}, R_{bg}, R_{af}, R_{bf} indicated in Fig. 14.

Forward Series Connection of Identical Nets Computed by Equivalent Symmetrical Sections.

A much simpler method for dealing with any given number of forward series nets loaded at the final pair of terminals with a known impedance, is illustrated in Figures 21, 22 and 23. It consists in substituting for the component dissymmetrical T of Fig. 5, whose arms are ρ_1 and ρ_2, a symmetrical T as in Fig. 21 of the same staff leak, but with arms equal to $(\rho_1 + \rho_2)/2$, the arithmetical mean of the original. Thus the four section T line of Fig. 21 has 1500 ohms in each and every branch. It will be seen that the symmetrical line thus produced differs from that corresponding in Fig. 19, by terminal impedances only, if we confine attention to conditions at the ultimate pairs of terminals. We therefore use the simple line of

symmetrical T's and introduce the required terminal corrections by Ohm's law.

Thus, if the fourfold dissymmetrical system of Fig. 19 is to be loaded at the EH terminals with σ = 500 ohms, and 100 volts are to be impressed at AG, we may require to know the conditions at the ultimate terminals, and also at section junctions along the system.

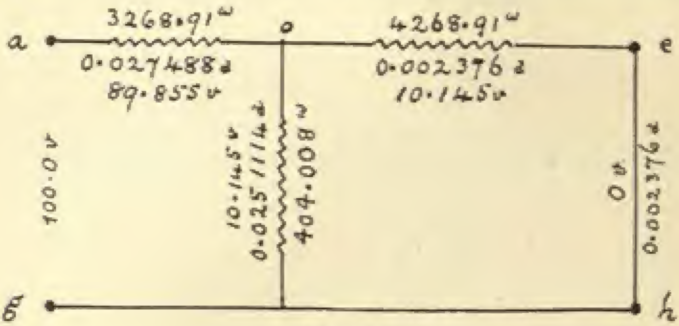

Fig. 20.

The sectional symmetrical T, with 1500 ohms in each arm, and 5000 ohms in the staff leak, has a versed sine of 1500/5000 = 0.3 or θ = 0.75643 hyp, q = 1, and z_0 = 4153.31 ohms. A load of 500 ohms applied to the EH terminals in Fig. 19, will be represented by a load e, f, of 1000 ohms in Fig. 22. The terminals AG in Fig. 19 will also locate themselves 500 ohms from A' in Fig. 22. The position angle at e when the load σ = 1000 ohms is $\tanh^{-1}$ (1000/4153.25) = 0.24559 hyp. The position angle at A' is 3.2713 hyps. The

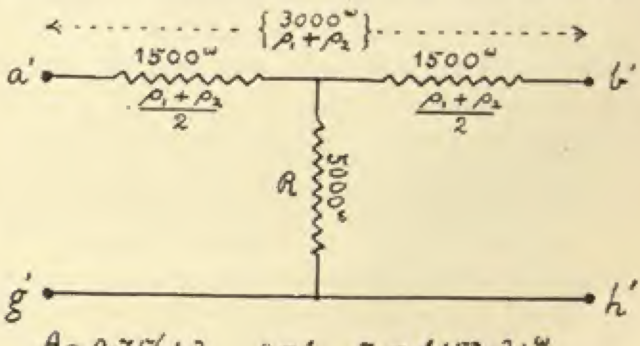

Fig. 21.

impedance offered at A' is 4153.31 tanh 3.2713 = 4141.36 ohms, and at A, 3641.36 ohms. This makes the entering current at A, under 100 volts, 0.027462 amperes.

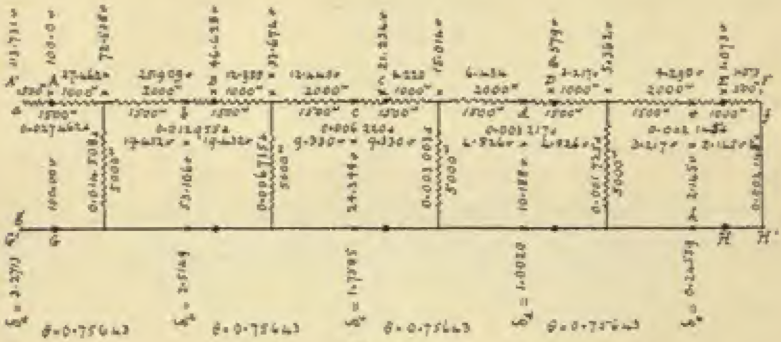

FIG. 22.

Finally we find the equivalent of the fourfold symmetrical system in Fig. 23, with $\Theta = 3.0257$ hyps and $z_o = 4153.31$ ohms. The two equal arms are $z_o \cdot \tanh(\Theta/2) = 3768.91$ ohms, and the staff leak $1/(y_o \cdot \sinh \Theta) = 404.008$ ohms. We must now reduce the arm

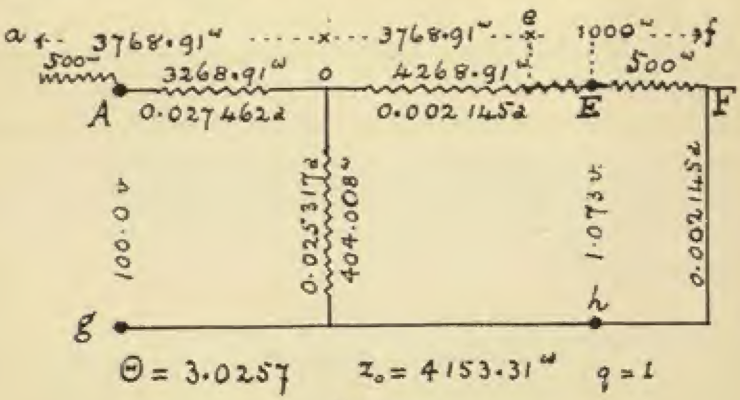

FIG. 23.

$a\,o$ by 500 ohms to $Ao = 3268.91$ and increase the arm o, e by 500 ohms to $OE = 4268.91$. The load is now ef or 1000 ohms for the symmetrical T, or $E\,F = 500$ ohms for the dissymmetrical T. This brings the system into agreement with Fig. 20.

Summary.

1. Identical nets presenting corresponding pairs of terminals, are represented by one and the same dissymmetrical T or one and the same dissymmetrical π, with its θ, q, and $z_{ab} = \sqrt{z_{oa} \cdot z_{ob}}$.

2. Such identical nets may be connected, two in series, in three ways: (1) back-to-back-B, (2) back-to-back-A, (3) forward series.

3. The back-to-back-B connection produces a symmetrical resultant T or π, with $\Theta = 2\theta$, $q = 1$ and $z_o = z_{oa}$ of component nets.

4. The back-to-back-A connection produces a symmetrical resultant T or π, with $\Theta = 2\theta$, $q = 1$ and $z_o = z_{ob}$ of component nets.

5. Further series connections of N back-to-back-B pairs or back-to-back-A pairs, produce symmetrical resultant T's with $\Theta = 2n\theta$, $q = 1$ and $z_o = z_{oa}$ or $z_o = z_{ob}$ respectively.

6. Forward series connection of N nets produces a resultant T whose arms have the same difference in impedance as any one component, and has the same z_{ab} as that of any one component, but the total resultant angle Θ and the resultant q are not simple expressions. They may be computed by the method of successive position angles.

7. The easiest method of dealing with forward series connections is to represent each section by a symmetrical T having the same total arm resistance as the actual section T and to consider the actual system of N forward nets as a simple artificial line of N such symmetrical sections. The final T then has the correct staff leak and its equal arms are adjusted to present the same difference as any actual component T.

List of Symbols Employed.

δ_A, δ_B, δ_D	Position angles along an artificial line (hyperbolic radians $\angle$).
E_A, E_B	Voltages at points A, B, on a line or system.
θ	Hyperbolic angle presented by a single net with respect to its two pairs of selected terminals (hyperbolic radians $\angle$).
Θ	Total hyperbolic angle presented by a series connection of nets (hyperbolic radians $\angle$).

I_A, I_B	Alternating or continuous current strengths at points A, B of a net or series connection of nets. $j = \sqrt{-1}$
N	Number of identical nets connected in series.
q	Inequality ratio $\sqrt{z_{oa}/z_{ob}}$ of a net or system (numeric $\angle$).
q'	Inequality ratio of a pair of forward series connected nets (numeric $\angle$).
R_{af}, R_{ag}	Impedance measured at AG terminals of a net when the BH terminals are respectively freed and shorted (ohms $\angle$).
R_{bf}, R_{bg}	Impedance measured at BH terminals of a net when the AG terminals are respectively freed and shorted (ohms $\angle$).
ρ_1, ρ_2	Impedances in the A and B arms of an equivalent T (ohms $\angle$).
σ	Load impedance at motor end of a net or system (ohms $\angle$).
$z_{ab} = \sqrt{z_{oa}z_{ob}}$	geomean surge impedance of a net or system (ohms $\angle$).
$z_{oa} = \sqrt{R_{af}R_{ag}}$	surge impedance at A end of a net or system (ohms $\angle$).
$z_{ob} = \sqrt{R_{bf}R_{bg}}$	surge impedance at B end of a net or system (ohms $\angle$).
z_o	surge impedance of a symmetrical system (ohms $\angle$).

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(Without pretensions as to completeness.)

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FINAL CONCLUSIONS ON THE EVOLUTION, PHYLOGENY, AND CLASSIFICATION OF THE PROBOSCIDEA.

By HENRY FAIRFIELD OSBORN.

(*Read April 25, 1925.*)

In 1900 I became interested in the past history of the Elephant and Mastodont Order and a quarter-century of exploration and intensive research has enabled me to reach certain final conclusions as to the birthplace of this remarkable group, as to the origin and dispersal of many of the branches to which it gave rise, as to the stages of evolution which all these branches display in common, and as to the characters distinctive of each branch separating it from all the others. On these common and distinctive characters is founded a new phylogenetic classification of the Proboscidea, very startling and novel to those conservatives who would embrace all the two hundred and ninety-odd species described from all parts of the world in two genera, namely: MASTODON and ELEPHAS!

Yet this new phylogenetic classification rests upon a most intensive comparison of every single type specimen, a comparison extended and enlarged by *all the other characters of each species and of each genus* which have thus far been discovered. A type may be a single tooth discovered long ago, *e.g.*, the type of *Mastodon mirificus* Leidy; we now know the entire skeleton and dentition belonging to this animal and no longer calling it *Mastodon* distinguish it as *Stegomastodon mirificus* of Nebraska, with close affinities to the *Pentalophodon sivalensis* of India and to the *Anancus arvernensis* of Auvergne, France. Together these and related species constitute a PHYLUM which arose in the Miocene of India.

Thus, irresistible evidence is accumulated against the older monophyletic theory, which would create a single line of descent passing from *Mastodon* through *Stegodon* into *Elephas*, and in favor of the firmly established polyphylogeny of from thirteen to twenty lines of proboscidean descent, four of which at least can be traced

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FINAL CONCLUSIONS ON THE EVOLUTION, PHYLOGENY, AND CLASSIFICATION OF THE PROBOSCIDEA.

By HENRY FAIRFIELD OSBORN.

(*Read Apri' 25, 1925.*)

In 1900 I became interested in the past history of the Elephant and Mastodont Order and a quarter-century of exploration and intensive research has enabled me to reach certain final conclusions as to the birthplace of this remarkable group, as to the origin and dispersal of many of the branches to which it gave rise, as to the stages of evolution which all these branches display in common, and as to the characters distinctive of each branch separating it from all the others. On these common and distinctive characters is founded a new phylogenetic classification of the Proboscidea, very startling and novel to those conservatives who would embrace all the two hundred and ninety-odd species described from all parts of the world in two genera, namely: MASTODON and ELEPHAS!

Yet this new phylogenetic classification rests upon a most intensive comparison of every single type specimen, a comparison extended and enlarged by *all the other characters of each species and of each genus* which have thus far been discovered. A type may be a single tooth discovered long ago, *e.g.*, the type of *Mastodon mirificus* Leidy; we now know the entire skeleton and dentition belonging to this animal and no longer calling it *Mastodon* distinguish it as *Stegomastodon mirificus* of Nebraska, with close affinities to the *Pentalophodon sivalensis* of India and to the *Anancus arvernensis* of Auvergne, France. Together these and related species constitute a PHYLUM which arose in the Miocene of India.

Thus, irresistible evidence is accumulated against the older monophyletic theory, which would create a single line of descent passing from *Mastodon* through *Stegodon* into *Elephas*, and in favor of the firmly established polyphylogeny of from thirteen to twenty lines of proboscidean descent, four of which at least can be traced

back to the great continent of Africa, the birthplace of the Order Proboscidea.

Birthplace of the Order.

In 1900 I first clearly set forth the hypothesis of Africa as *a great center of independent evolution* and as a *source of successive northward migrations of mastodonts*, one branch of which ultimately reached South America. An African invasion of great distinctness was that which marked the close of Oligocene time, when the Mastodonts and Dinotheres left Africa and entered Europe. This African migration is graphically displayed in the accompanying chart (Fig. 1). This Chart IV of 1900 has proved highly prophetic and has been largely confirmed by discoveries made in the years 1901–1903 in Africa and in the years 1922–1923 in central Asia, represented herewith. It displays four great centers of adaptive radiation of the orders of mammals, namely:

I. Africa

Proboscidea
Archæoceti
Hyracoidea
Sirenia
Lemuroidea

II. Central Asia

Insectivora
Cheiroptera
Creodonta
Carnivora
Tillodontia
Rodentia
Taeniodonta
Primates
Mesodonta
Amblypoda
Condylarthra
Perissodactyla
Ancylopoda
Artiodactyla

India

Anthropoidea

III. Australia

Monotremata
Marsupialia

IV. South America

Edentata
Litopterna
Toxodontia
Typotheria

Oceanic

Mystacoceti
Odontoceti

These three facts seem to establish the African theory of origin: First, four great branches of the Proboscidea have been found in Africa in Oligocene or Lower Miocene time, none has been found in

FIG. 1. Chart of 1900 as modified in 1922, showing Osborn's theory of 1900 as to the birthplaces of the orders of mammals.

Oligocene Eurasia; second, the proboscideans which arise in Oligocene Africa suddenly appear in the Lower Miocene of Eurasia, and, third, there is no evidence that any proboscideans passed southward from Eurasia into Africa.

Far back in Eocene and Oligocene times the Proboscidea branched into four great stocks, namely:

I. The Mœritheres (MŒRITHERIOIDEA). Small, amphibious and palustral, with opposed upper and lower tusks.

II. The Dinotheres (DINOTHERIOIDEA). Large, palustral and terrestrial, with down-turned lower tusks only, sharply crested teeth.

III. The Mastodonts (MASTODONTOIDEA). Large upper and small lower tusks, bluntly crested grinders; chiefly browsers.

IV. The Stegodonts and the Elephants (ELEPHANTOIDEA). Upper tusks only; chiefly browsers and grazers.

The widest variation is: (1) In the various forms of use or of disuse of the lower tusks; (2) in the absence (Dinotheres) of the upper tusks; (3) in the absence (Elephantoidea) of the lower tusks; (4) in the compensatory evolution of the grinding teeth. In the exact measure that the tusks, upper or lower, cease to function, the grinding teeth rise to the emergency and increase their function. For example, in all mammoths in which the superior tusks cease to function as feeding organs, the grinders reach the highest degree of complication. As in other ungulates, the scale of dental complication is an ascending one, from the lush food of the amphibious and palustral Mœritheres to the leafy and woody fibers of the mastodonts browsing in the forests and savannas, seen in the increasing length of the crown and complication of the enamel as we pass from the forest-living Stegodonts and the forest-browsing Loxodonts into the chiefly grazing true Mastodons, and, geographically, from forests into grassy plains and savannas and finally into the grassy northern steppes.

I. The Mœritheres (Mœritherioidea).

Race I, The Mœritheres.—The Mœritheres, named from Lake Mœris of the Greeks, are small amphibious promastodonts of the North African rivers and lakes; of Lower Oligocene age they are the oldest, the most primitive, and the most diminutive probo-

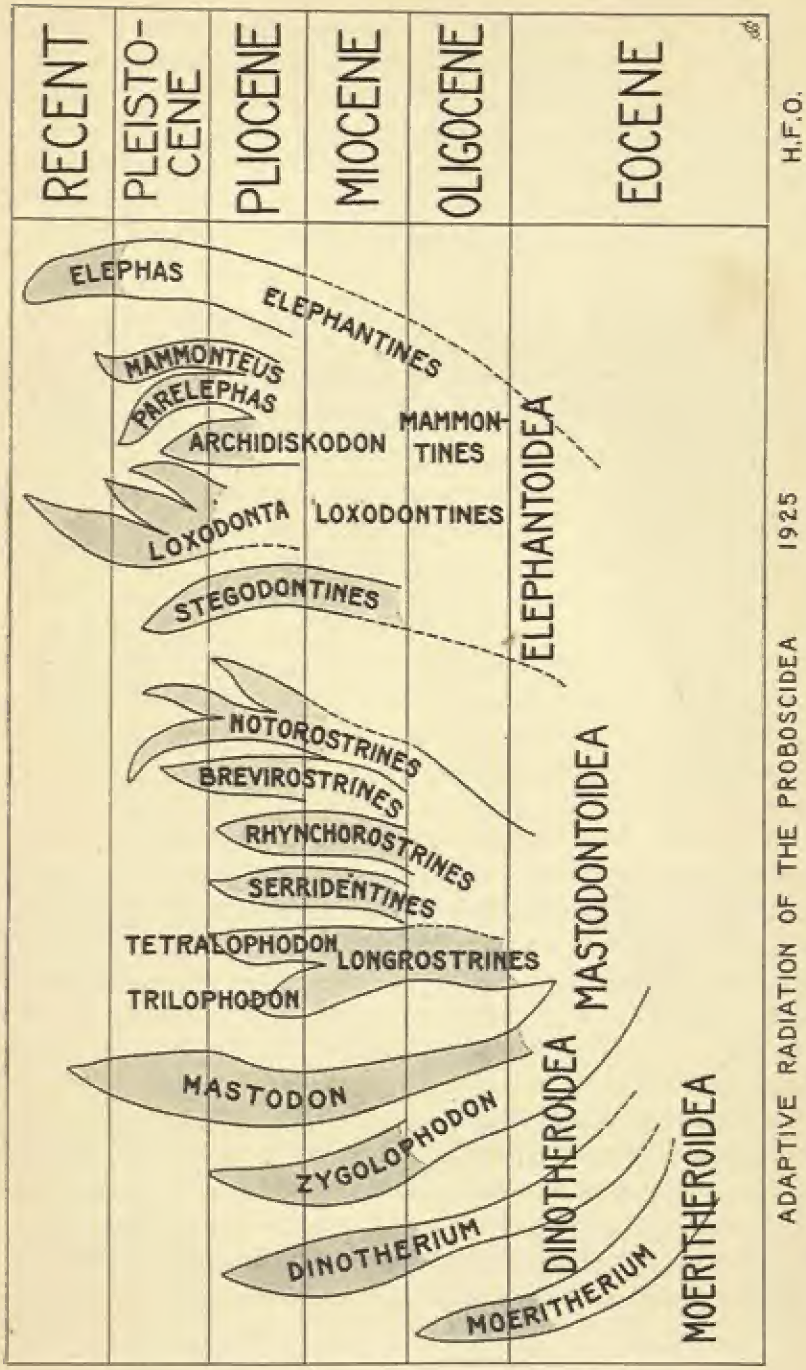

FIG. 2. Diagram showing Osborn's theory of 1925 as to the relationships, chief lines of descent or phyla, of the Proboscidea.

scideans known. A single pair of enlarged upper and lower tusks, enamelled in front, abrade each other, as in the *Hippopotamus*. This is the same second pair of incisors which is enlarged in all proboscideans. The primitive grinding teeth are archetypal to those of the higher mastodonts. The Mœritheres disported abundantly in the estuaries and rivers of North Africa but are not known to have migrated northward or to have left African or Eurasiatic descendants.

II. The Dinotheres (Dinotherioidea).

Race II, The Dinotheres.—Sharply distinguished from all other proboscideans are the Dinotheres, first, by the entire loss of the upper tusks, second, by the powerful down-turned lower tusks, and, third, by the sharply crested tapir-like teeth. Confirmatory of their African origin is the new *Dinotherium hobleyi* from the east side of Victoria Nyanza, of Lower or Middle Miocene age. With powerful defensive tusks and elevated limbs, almost like those of the elephants, they immediately began their northward and eastward migration throughout the Miocene of Europe, attaining gigantic size in the *Dinotherium gigantissimum* of Roumania, spreading all over southern India, but not, so far as we know, penetrating eastward as far as China and still less approaching the American continent. They survived into early Pliocene time.

III. The Mastodonts (Mastodontoidea).

These animals, embraced until recently within the single genus *Mastodon*, surpassed even the true elephants in their worldwide migration, passing with great rapidity through Eurasia into North America and finally, in one of their branches, reaching far down into South America. Highly intelligent, resourceful, well defended by their giant tusks, they multiplied rapidly, doubtless they felt the pressure of an unchecked increase in numbers; they reached out in every forested region for every kind of browsing food, for every kind of browsing habitat, whether in forests, pastures, fields, along rivers or streams, becoming adapted to all possible conditions of browsing life, even producing a desert-living form. In fact one of the most astonishing results of this research is the adaptive radiation of the Mastodonts into two main families, the Mastodontidæ and the

Bunomastodontidæ, and into no less than eight subfamilies, all very clearly distinguished from each other. These main and subsidiary branches may be set forth as follows:

FAMILY: MASTODONTIDÆ. Mastodonts of the Eurasian and American forests, distinguished by simple crests, springing from *Palæomastodon* of northern Egypt.

Race III. TRUE MASTODONS, springing directly from *Palæomastodon* of northern Egypt; typical of the northern forests of Eurasia and of North America.

Race IV. THE YOKE-TOOTHED MASTODONTS, OR ZYGOLOPHODONTS, typified by Borson's mastodon of the Eurasian forests.

BUNOMASTODONTIDÆ. The Bunomastodonts, distinguished by trefoils or conelets in the valleys between the main crests.

Race V. THE LONG-JAWED MASTODONTS, OR LONGIROSTRINES, springing directly from the long-jawed *Phiomia* of the North African Oligocene, becoming the Miocene *Trilophodon* of Europe and Asia, and the Pliocene *Trilophodon* of the northern United States.

Race VI. THE TETRALOPHODONTS, the name referring to the four ridge-crests on the anterior molar teeth; typical of the Lower Pliocene of Germany, of Greece, and of India, and surviving in America almost until the Ice Age.

Race VII. THE SERRIDENTINES, mastodonts with jaws of medium length, serrate outer and inner borders of the grinding teeth; discovered in the Miocene forest deposits of Europe; migrated to our southern and southeastern states, Texas and Florida, surviving to the close of the Pliocene.

Race VIII. THE BEAK-JAWED MASTODONTS, OR RHYNCHOROSTRINES, distinguished by the downward curvature both of the upper and lower tusks; first appearing in northern Africa, reappearing in Colorado and California, traced down into Mexico.

Race IX. THE NOTOROSTRINES, signifying "mastodonts of the south"; discovered in southern Texas, in Nebraska, in southern California, and taking full and exclusive possession of the continent of South America.

Race X. SHORT-JAWED MASTODONTS, OR BREVIROSTRINES, arising in the straight-tusked mastodont of Auvergne, France, migrating across India, reaching Nebraska, and penetrating the desert region of Texas.

RACE III, THE TRUE MASTODONS.—It now appears probable that the diminutive *Palæomastodon* of the primordial river Nile was most appropriately named and that it gave rise to the giant mastodon (*Mastodon americanus*) so abundant in the forests of eastern North America. Remains of the Upper Oligocene *Palæomastodon* are comparatively rare, and the reason why we have so little trace of the long journey of these animals from the borders of the Nile to the borders of our American rivers, the Ohio and the Hudson, is that remains of forest-living animals are always extremely rare. It is only when we arrive at the forest-bed deposits of our central and eastern states that fossil remains are discovered by the thousand. If this line of descent is confirmed, it will furnish one of the romances of palæontology and of animal migration.

RACE IV, THE YOKE-TOOTHED MASTODONTS, OR ZYGOLOPHODONTS.—Most interesting is the complete separation from our true American mastodon of the long line of yoke-toothed mastodonts of the forests of southern Europe under the name *Zygolophodon*, proposed by Vacek in 1877. The distinction is in the formation of the crest in *Zygolophodon*, which is almost as sharp as that in *Dino-*

therium or in the tapirs; thus, the first species found by Cuvier was named *tapiroides*. The scanty Miocene remains of these animals are invariably found in lignitic deposits, signifying that they were swamp dwellers; this branch terminates in the large Upper Pliocene form named *Mastodon borsoni* by Hays, the American palæontologist; the species has been traced eastward into Russia by Buffon and Pavlow.

RACE V, THE LONG-JAWED MASTODONTS, OR LONGIROSTRINES.—In these animals the jaw became longer and longer until it attained the surpassing length of six feet seven inches, reaching the ground. A pair of shovel-shaped lower tusks was used in uprooting plants, while the upper tusks served as weapons of offense and defense. The indubitable ancestors of these animals are four species of *Phiomia* discovered in the Fayûm of North Africa (= *Phiomia minor*, ?*P. serridens*, *P. wintoni*, and *P. osborni*), successively increasing in size until *P. osborni* almost attains the length of smaller examples of the famous *Trilophodon angustidens* of Europe.

Thus arising, this extraordinarily successful long-jawed phylum spread rapidly all over western Europe, through India, reaching the plains region of North America in Lower Pliocene time and giving rise to numerous long-jawed species recently discovered in South Dakota, in Nebraska, and in Colorado by Erwin H. Barbour, Harold Cook, and E. L. Troxell. This phylum culminates in the ponderous *Trilophodon giganteus* discovered by Troxell in South Dakota, which persisted well into Pliocene time, if it did not reach the summit of the Pliocene.

RACE VI, THE TETRALOPHODONTS.—In contrast to the Trilophodonts, in which the anterior molar teeth have three ridge-crests, all species of *Tetralophodon* possess four ridge-crests. Compared with the excessively long slender jaw of *Trilophodon*, the jaw of *Tetralophodon* is of medium length, although the first species discovered was named by Kaup *Mastodon longirostris*. The earliest appearance of members of this phylum is in the Miocene of Italy, whence they apparently migrated into the region of Eppelsheim, Germany, and thence eastward across India into North America, where they are first discovered in the Lower Pliocene *Tetralophodon campester*, found on the borders of the Republican River, Kansas.

From this primary American stage a successive series of Tetralophodonts evolved, known by grinding teeth of increasing complication, until the *Tetralophodon* (*Morrillia*) *barbouri* stage was reached of the Upper Pliocene.

Race VII, The Serridentines, or Serrate-toothed Mastodonts.—Like the Zygolophodonts, these animals are first known in the Miocene forests of Europe; they are traced into the ancient forest bed of Austria; a single specimen (*Serridentinus mongoliensis*) was fortunately discovered in the northern portion of the desert of Gobi; they migrated especially to our southern states where they are found in the *Serridentinus productus* of Cope, also in the southeastern United States where they gave rise to the *Serridentinus obscurus* of Leidy and to the largest and most recent species, *Serridentinus floridanus*, thus surviving to the very close of Pliocene time.

Race VIII, The Beak-jawed Mastodonts, or Rhynchorostrines.—Unlike the preceding phyla of Longirostrines, Tetralophodonts, and Serridentines, these animals have a broad enamel band on the outer side of their superior and inferior incisive tusks and both these tusks have a sharp downward curvature. The rostrum of the lower jaw is swollen into a down-curved beak; consequently they are distinguished as the "beak-jawed" mastodonts. Possibly the ancestor of this phylum is the *Mastodon spenceri* of North Africa, described by Colonel Fourtau. A few scattered specimens have been found in Colorado and California, but these animals do not become abundant until we discover them in the high plateaus of Mexico, where their remains are mingled with those of the next phylum, the Notorostrines.

Race IX, The Notorostrines.—Typified by the *Mastodon andium* and the *M. humboldtii* of Cuvier, these short-jawed South American mastodonts are among the most famous species in the whole history of mammalian palæontology. It is only recently, through the researches of Marcellin Boule and of Osborn, also through the discoveries of Cope and of Frick, that we have been able to clearly distinguish from the genus *Mastodon* Cuvier these two widely separated South American genera, named respectively *Dibelodon andium*, after the typical Andean species with enamel

ribbons on its tusks, and *Cuvieronius* (*Mastodon*) *humboldtii*, specifically named by Cuvier in honor of von Humboldt, generically by Osborn in honor of Cuvier himself. *Dibelodon andium* was distinctly the mastodont of the forests and mountains, while *Cuvieronius humboldtii* preferred a plains and pampas habitat, although this distribution is not conclusive.

RACE X, THE BREVIROSTRINES, OR SHORT-JAWED MASTODONTS.—The Brevirostrines apparently originated in the Upper Miocene *Anancus perimensis* of India. These animals were first distinguished by a peculiar twisting of the inner and outer cones of the grinding teeth, a character clearly displayed in the Upper Pliocene *Anancus arvernensis* of Auvergne, France, which traveled even farther northwest into the British Isles. In the India center these Brevirostrines developed into the *Pentalophodon sivalensis* of Falconer, but before reaching this stage gave off the American branch which reached western Nebraska in Upper Pliocene time, as first discovered by Leidy in his *Mastodon mirificus*, so named because of the marvelous plication of the enamelled grinding teeth; they then traveled down into our southwestern states. This animal appears to have been the first to adapt itself to a purely desert habitat, because it was found in the ancient playa lakes of Arizona in the species *Stegomastodon arizonæ* Gidley.

IV. THE STEGODONTS AND THE ELEPHANTS (ELEPHANTOIDEA).

The Elephantoidea are uniformly distinguished from the Mœritherioidea, the Dinotherioidea, and the Mastodontoidea by the extremely early loss of the lower incisor teeth and by the correspondingly supreme development of the superior incisor teeth into the long straight tusks of *Stegodon ganesa*, into the long, powerful, slightly up-turned tusks of the African elephant (*Loxodonta*) and of the true elephant (*Elephas*), all of which are very extensively and continuously used in the collection of food, either in the uprooting of plants or in the down-turning of branches. This useful function continues to a very advanced age in *Loxodonta* and *Elephas*, whereas in all three of the mammoths (*Archidiskodon*, *Parelephas*, and *Mammonteus*), the tusks turn inwards and completely cross each other in old age, thus being no longer of use for feeding purposes;

this incurving of the tusks is accompanied by extreme fore-and-aft abbreviation of the skull.

Where the tusks are used most, as in the Stegodonts and the African Elephants, the grinding teeth are less complex; in the true elephants (*Elephas*), where the tusks are less powerful and not as frequently used, the grinding teeth become more complex; in the mammoths (*Mammonteus*), where the tusks are the least used, the teeth become the most complex. This compensation or economy of growth principle as between the tusks and the grinders is thus again illustrated among the Proboscidea.

FAMILY: ELEPHANTIDÆ, distinguished by plated grinding teeth developing out of the more or less closely compressed, serrated ridges of *Stegodon* into the broadly plated grinders of *Archidiskodon*, the lozenge-shaped grinders of *Loxodonta*, and the compressed, finely plated grinders of *Parelephas*, of *Mammonteus*, and of *Elephas* the type genus of the family.

Race XI. THE STEGODONTS. Apparently traced from the Miocene of Europe into the forests of India, of the East Indies, and of western China; essentially dwellers in the tropical and more or less arid, lush forests of the East Indies.

Race XII. THE AFRICAN ELEPHANTS, OR LOXODONTS, distinguished by their lozenge-shaped grinders; related to the diminutive species of the Mediterranean islands and to the giant *Loxodonta antiqua* of western Europe and the *Loxodonta namadica* of southern Asia and of the Asiatic islands.

Race XIII. THE SOUTHERN MAMMOTHS, OR ARCHIDISKODONTS. Excessively broad-plated grinders with abundant cement; first known in India, migrating westward into southern Europe, eastward into America, where arriving in late Pliocene or early Pleistocene time they finally gave rise to the Imperial Mammoth, *Archidiskodon imperator*, the last of its race.

Race XIV. PARELEPHAS, THE NORTH TEMPERATE MAMMOTHS, a phylum intermediate between the true boreal mammoths (*Mammonteus*) and the southern Archidiskodonts, and in many ways collateral to the development of the true *Elephas;* favoring the forests and savannas of the temperate zone; first known in the Upper Pliocene and Lower Pleistocene of Europe, traced into America, where they gave rise to the great Jeffersonian Mammoth, *Parelephas jeffersonii.*

Race XV. THE WOOLLY MAMMOTHS (MAMMONTEUS), typified by the boreal *Elephas primigenius* of Blumenbach. These hardy and somewhat dwarfed mammoths of the northern tundras and steppes crossed northern Asia and arrived in America in late Glacial times.

Race XVI. THE TRUE ELEPHANTS (the *Elephas* of Linnæus). Of unknown ancestry, probably originating in the plains of northern Asia; first known in India early in the Age of Man and giving rise to the recent geographic varieties of India, Burma, and Ceylon.

RACE XI, THE STEGODONTS.—From Miocene to Pleistocene time, these very primitive elephants known as Stegodonts were dwellers in the tropical forests, extending from India and the East Indies to China. Differing from the mastodont family, the Stegodonts have a new kind of grinding tooth with multiple ridge-crests, from which the grinding teeth of all the higher elephant races may have been derived, and it is not improbable that a certain primitive branch of the Stegodont family wandered into northern Asia and was there transformed into some of the primitive members of the elephant family; such transformation certainly did not occur in southern Asia, where the Stegodonts have their own independent history that culminated in the prodigious and widespread Stegodontines, which left their fossil remains in the same deposits with the earliest of the mammoths. The best-known among these giant Stegodonts is the species *Stegodon ganesa*, named after one of the

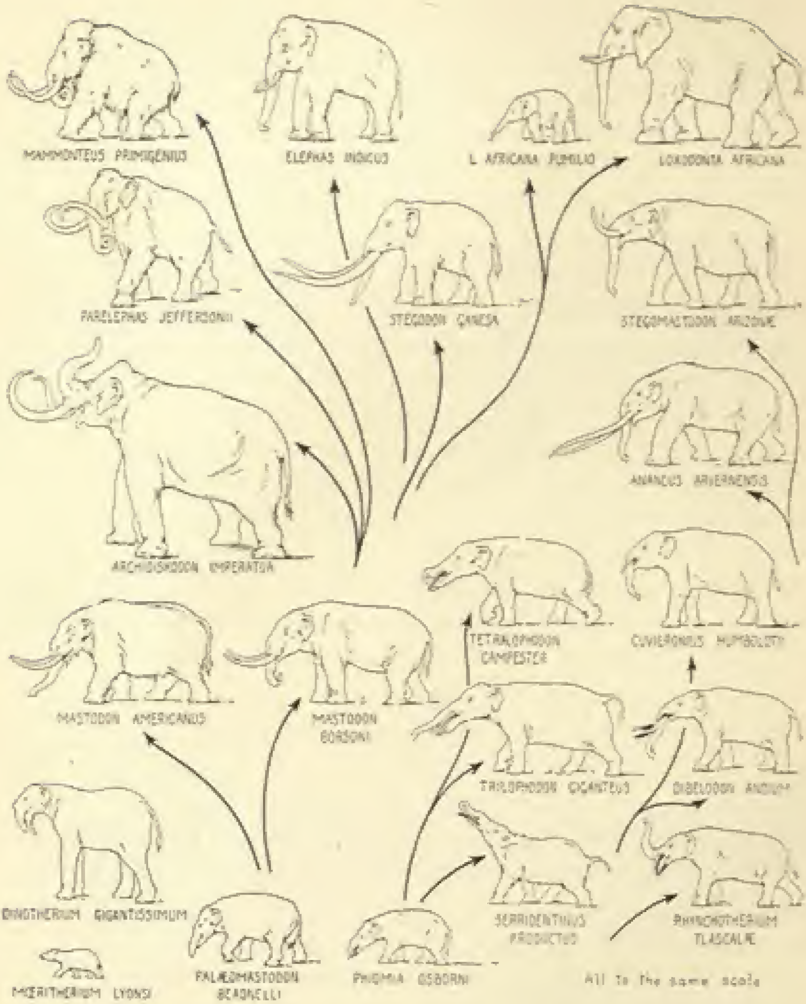

FIG. 3. Diagram to be compared with that of Fig. 2, showing Osborn's theory of 1925 of the relationships, phylogeny or lines of descent, of the chief genera of the Proboscidea.

legendary deities of India. It is contemporary with a giant true elephant related to the African.

RACE XII, THE AFRICAN ELEPHANTS, OR LOXODONTS.—We know little of the direct ancestral history of the true African Elephant, *Loxodonta africana*, because none of the fossil elephants of Africa shows the true lozenge-shaped patterns on the surface of the grinding teeth, to which the name *Loxodonta* refers. From the vast unexplored strata of central Africa we look forward constantly to the filling in of this missing chapter in proboscidean history.

Osborn has recently proposed the new genus *Pilgrimia* for the numerous fossil elephants of Africa and of the Mediterranean islands which, while related to *Loxodonta* in the structure of the skull, differ in the long and very narrow grinding teeth with numerous and closely compressed ridge-plates, quite unlike the lozenge-shaped ridge-plates of *Loxodonta*. There are no less than thirteen species distributed all over Africa and the Mediterranean islands, from Zululand on the south to Cyprus and Crete on the north.

Osborn has also distinguished as *Sivalikia* the giant elephants of southern Eurasia, characterized by relatively broad grinding teeth with numerous ridge-plates and by the absence or rudiment of the "loxodont sinus," the cranium resembling that of the true African Elephant. Five species are embraced in this genus, namely, *Loxodonta namadica* of India, *L. antiqua* of western Europe, and three ancestral species.

RACE XIII, THE SOUTHERN MAMMOTHS, OR ARCHIDISKODONTS.—The phylum *Archidiskodon*, signifying "primitive ridge-plates," takes its name from the adaptation of the grinding teeth to shrub-browsing and to the crushing of great masses of leaves and twigs; the ridge-plates are very far apart and the enamel bands are broad. The phylum rises in the *Archidiskodon planifrons* of the Upper Pliocene of India, from which is descended the giant *Archidiskodon meridionalis* or Southern Mammoth of the Pliocene and Lower Pleistocene forests of Italy, France, and the British Isles, whence it wandered to America in Upper Pliocene or Lower Pleistocene time where this majestic animal was discovered in Nebraska by Ferdinand Hayden, exploring geologist, and aptly described by Joseph Leidy in 1858 as *Elephas imperator*. This name, signifying

the "imperial elephant," given in reference to the surpassing size of the grinding teeth, is also appropriate through our more recent knowledge of the impressive height of the animal, justified by discoveries of remains of this gigantic animal in Nebraska, Kansas, Iowa, Texas, California, and Mexico, consisting of portions of teeth, skulls, and skeletons sufficient to establish the fact that the full-grown animals attained a height of 13½ to 14 feet, exceeding by 2½ feet the tallest of the existing African elephants and rivaled only by the gigantic straight-tusked elephant of India, and of western Europe known as *Loxodonta antiqua*. The phylum apparently becomes extinct in Lower Pleistocene time both in Europe and America.

RACE XIV, PARELEPHAS, THE NORTH TEMPERATE MAMMOTHS.—It has taken many years of study to disentangle the lineage of this great immigrant from that of the Southern Mammoths on the one hand and that of the Woolly Mammoths on the other. With the aid of Prof. Hans Pohlig of Bonn and of Prof. Charles Depéret of the University of Lyons this lineage has been traced back to Germany, to southern France, and to the British Isles, and it is now a well established fact that the Jeffersonian Mammoth came from smaller and more primitive ancestors which wandered in the north temperate forests and meadows of western Europe during the first half of the Age of Man. These European forebears replaced the ancestors of the Imperial Mammoth and were in turn replaced by great herds of the Woolly Mammoth that entered Europe in the closing period of the Age of Man. These animals are so distinct from either the Imperial or Woolly Mammoth stock that we have given them the separate generic designation of *Parelephas*, in allusion to their development parallel with the true elephants of India. Whereas the European branch of *Parelephas* became extinct, the American branch flourished exceedingly in the temperate regions of the United States, and its fossil remains are far more numerous than those of either the Imperial or the Woolly Mammoth; *Parelephas* also endured for a long period of time and underwent a considerable evolution in respect to its grinding teeth, from an earlier stage which we have named *Parelephas jeffersonii*, in honor of President Jefferson, to a final stage (*Parelephas jeffersonii progressus*) in which the third

upper molar possessed as many as thirty plates and the third lower molar twenty-six.

Second only in size to the Imperial Mammoth, the Jeffersonian Mammoth succeeded its imperial forerunner and survived the severe climate of the Fourth Glaciation, at the close of which it became extinct.

RACE XV, THE WOOLLY MAMMOTHS OF THE GENUS MAMMONTEUS.—It appears probable that European palæontologists have mistaken the teeth of *Parelephas* of Lower Pleistocene time for those of *Mammonteus* and that the true Woolly Mammoth appears in central Europe, as in North America, only near the close of Pleistocene time. Also it now seems that late in the Age of Man, during the Fourth Glacial period, the *Elephas primigenius* from the northern steppes and tundras of western Europe descended into Germany and France. The first to make comparison between this west European race and the American varieties was Dr. Hugh Falconer, who declared that while the same number of enamel ridge-plates was present in the forms of both regions, namely, twenty-four in the last molar of each jaw, the American animals were in general characterized by still finer and more compressed ridge-plates than those of western Europe. Thus we may distinguish one of our own forms as *Mammonteus primigenius americanus*, while in Indiana and in Alaska we find a type of mammoth with close-fitting enamel ridge-plates to the number of twenty-seven and of such exceeding fineness that we have named it *Mammonteus primigenius compressus*. This adaptation of the grinding teeth for grazing habits was to enable the animal to feed upon the hard grasses which covered the tundras and steppes of the north during the summer season. Thus the Woolly Mammoth was chiefly a grazer, as proved by the stomach contents of frozen carcasses recovered from the ice in Siberia.

RACE XVI, THE TRUE ELEPHANTS OF THE GENUS ELEPHAS OF LINNÆUS.—The history of the true genus *Elephas indicus* of Linnæus still lies buried in the rocks of the great Eurasiatic continent north of India, for as our knowledge stands at present the true Indian Elephant suddenly appears in India during the latter part of the Age of Man and all attempts to derive this animal directly either from Race XI (the Stegodonts) or from Races XIII to XV (*Archi-*

diskodon, Parelephas, Mammonteus) do not stand the test of the higher criticism of palæontologists. The profound reason for this new point of view taken by the present writer is that, while the grinding teeth of *Elephas indicus* are superficially similar to the grinding teeth of several of the species of *Parelephas*, the cranium of the two animals is profoundly different, also the use and form of the tusks; the *E. indicus* cranium is rounded, bulbous, and relatively longer than the extremely abbreviated cranium of *Parelephas;* in *E. indicus* the tusks are used to the very end of the life of the animal, whereas in *Parelephas* the tusks cross each other in old age and can no longer be used in the prehension of food.

Thus the Proboscidea, included within the two genera *Mastodon* and *Elephas* by Richard Lydekker in 1886, have actually diverged into twenty-eight generic and subgeneric phyla, as distinguished up to the present time, with other phyla doubtless remaining to be discovered. These generic and subgeneric phyla are as follows:

Mœritherium	*Lydekkeria*	*Stegolophodon*
Dinotherium	*Morrillia*	*Stegodon*
Palæomastodon	*Serridentinus*	*Loxodonta*
Phiomia	*Rhynchotherium*	*Sivalikia*
Mastodon	*Cuvieronius*	*Pilgrimia*
Miomastodon	*Dibelodon*	*Archidiskodon*
Zygolophodon	*Eubelodon*	*Parelephas*
Trilophodon	*Anancus*	*Mammonteus*
Tetralophodon	*Pentalophodon*	*Elephas*
	Stegomastodon	

The primary genera, *Mœritherium*, *Palæomastodon*, and *Phiomia*, are represented by three to four species each, as analyzed by Matsumoto and Osborn; most of the remaining genera are represented by species varying in number. While some of these genera are better known than others, there is little doubt that the more fully we know them the more numerous will be found the generic differences which distinguish them. Thus the Proboscidea, formerly regarded as almost monophyletic, are shown to be highly poly-

phyletic, because each of the twenty-eight genera or subgenera represents a long series of ascending mutations and species. Consequently the phylogenetic diagram, which displays this worldwide adaptive radiation, exhibits four main stems indicated in the terminal OIDEA, five great family branches indicated in the terminal IDÆ, thirteen subfamily branches indicated in the terminal INÆ, and twenty-eight generic branches, as listed above.

American Museum of Natural History,
New York.

SOME NEW EXPERIMENTS IN GRAVITATION.

FIFTH PAPER.

Change in Weight of Metals under Strain.

By CHARLES F. BRUSH.

(Read April 24, 1925.)

The writer has heretofore presented six papers on the subject of gravitation,[1] the last four of which have been under the present title, and numbered. These four papers have cited in detail much evidence to the effect that the relation between weight and inertial mass (mass-weight ratio) differs very considerably in certain different substances; very much more than probable experimental errors can account for. The last of the four papers contains a summary of ratio differences found, and a brief discussion of them. It should be studied by all interested in this important subject.

The present paper introduces another phase of the subject viz., change in mass-weight ratio in the *same* substance by change of physical condition.

Toward the close of the third paper referred to, the writer cited reasons for believing that mass-weight ratio in some metals is not constant, but varies slightly with physical condition. In other words, that a constant mass, or quantity of metal may be appreciably changed in weight by changing its physical condition.

A very large amount of careful experimental work has been expended on this problem during the last three or four years, particularly during the last year and a half. The earlier efforts were directed to finding a practicable, reliable and efficient method of attack. These efforts were finally successful.

The best method of procedure consists in certain heat-treatment of the metal to bring about a definite molecular or crystalline condition, before the first weighing. This is essential. After weighing,

[1] *Science*, March 10, 1911; *Nature*, March 23, 1911. *Proc. Am. Phil. Soc.*, Vol. LIII., No. 213, January–May, 1914; Vol. LX., No. 2, 1921; Vol. LXI., No. 3, 1922; Vol. LXII., No. 3, 1923; Vol. LXIII, No. 1, 1924.

the metal is subjected to more or less drastic and sustained pressure, usually in many stages, with occasional periods of rest to permit the spontaneous changes which sometimes occur, and re-weighed after each stage of treatment. The treatments are so conducted as to preclude any loss or gain of substance.

Following is a detailed account of such procedure, and apparatus employed.

PREPARATION OF METAL FOR TESTING.

Fig. 1 shows in vertical axial section a conical assay crucible of fire-clay *A* about 13 cm. high. *B* is a tube of pyrex glass about 1.7 cm. inside diameter, open at both ends and centrally located in the

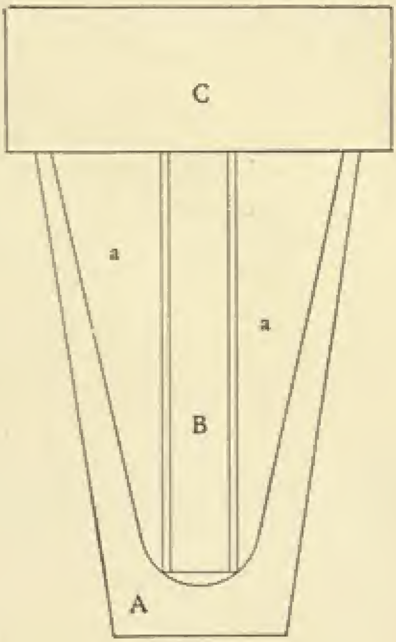

FIG. 1.

crucible. The space *aa* between the tube and crucible is packed with very fine dry molding sand. This is a slow conductor of heat. *C* is a thick block of "silocel" covering the crucible and its contents. Silocel is a *very* poor conductor of heat.

The metal to be treated is first cast in an iron mold to form a cylinder 1.6 cm. diameter, so as to fit loosely in the pyrex glass tube. A sufficient length is cut nearly to fill the tube, and lowered into it.

The whole is then placed in a large electric muffle furnace, provided with a pyrometer, and already heated to something like the melting point of the metal. The temperature is then raised to about 200° C. above the melting point and maintained there by a rheostat in the heating circuit. This procedure causes melting of the metal from the bottom upward, and thus insures absence of air bubbles. When melting is complete, the silocel block is removed from the top and placed at the side of the crucible. Heating is continued half an hour to secure approximate uniformity of temperature throughout. Then the silocel block is replaced on top of the crucible, the heating current stopped and all left to cool many hours in the furnace.

Several important things happen during the cooling. (1) The slow passage of the metal through the freezing process yields comparatively large crystal grains. (2) Solidification proceeds from the lower end upward, thus giving a sound casting, except at the upper end, which is often somewhat spongy. This is cut off and discarded. In the case of an alloy, some segregation may occur. For instance, a zinc aluminum alloy containing 5 per cent. of aluminum was found by analysis to be a little richer in aluminum at the upper end than at the lower end. (3) As the zone of solidification creeps upward, cooling occurs both at the bottom and circumference of the zone, whereby direction of the crystal grain growth is diagonal to the axis of the cylinder; because grain growth is always normal to the cooling surface. This condition is sought, and is believed to be highly beneficial. A cylinder prepared in this way yields much more readily to end pressure than when the grain growth is either longitudinal, or transverse to the axis.

Finally, the metal cylinder is removed by cutting away the glass tube with a diamond, and machined to the desired dimensions either as a solid cylinder or thick-walled tube. In doing this, the metal casting is much reduced in diameter, and better results are obtained than when a smaller casting is made requiring but little removal of surface. Thus it appears that the outer portion of the casting is the less effective.

That very slow cooling of the melted metal as described above is essential to the highest success is evidenced by the fact that if the

covered crucible, ready for cooling, be removed from the furnace and allowed to cool (much more rapidly) outside the furnace, the effects produced by subsequently stressing the metal are comparatively small.

Pressure Devices.

Figs. 2 and 3 illustrate two forms of device for exerting compressive stress on a specimen of metal or alloy under examination, and permitting accurate weighing in both unstressed and stressed

Fig. 3.

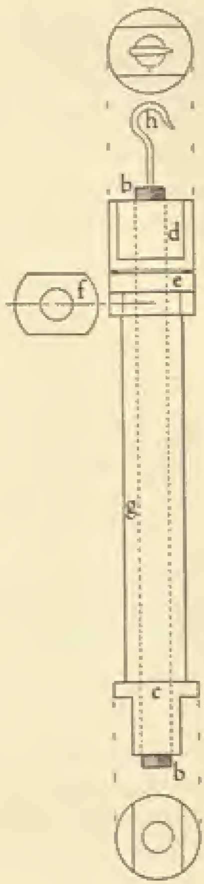

Fig. 2.

condition. All parts, except the brass suspension hooks *h*, and steel step *i* of Fig. 3, are made of duralumin alloy heat treated and worked for greatest strength. This material is eminently well suited for the purpose because it is nearly twice as strong as cold drawn brass, has only about a third of its weight, and does not tarnish in normal air.

The device shown in Fig. 2, the first form used, consists of a central rod *b*, .8 cm. diameter, threaded at both ends (.75 mm. pitch) and provided with a fixed nut *c* at its lower end and a compression nut *d* at its upper end. The nuts are made long enough to embrace more than two diameters of the threaded rod so as to avoid stripping the thread when the central rod is stressed nearly to its elastic limit. The compression nut *d* is beveled at its lower end to reduce its radius of friction on the friction collar *e*, and so that the small quantity of oil used between the surfaces of friction cannot spread to the outer surface of the nut. The extra collar *f* is adapted to be held against rotation by an aluminum wrench when the compression nut *d* is advanced against heavy pressure, and thus avoid torsional stress on the specimen *g* being tested. The latter is in the form of a hollow cylinder just freely fitting the central rod, and is smoothly machined to such external diameter as will afford a cross-section within the crushing capacity of the device.

This device (Fig. 2) has worked well for the softer metals lead, bismuth, cadmium, tin and aluminum and the softer alloys; but is not sufficiently powerful for the harder metals and alloys. And it requires accurate boring of the cylinder, which is troublesome, and involves loss of the central portion of the annealed metal which is thought to be the most valuable part.

A more powerful device is shown in axial cross-section in Fig. 3. It consists of a thick-walled tube *k* with a long screw-plug in each end, 1.25 mm. pitch of thread. The upper plug *l* is beveled at its lower end which rests on the polished steel step *i*. This friction contact is oiled. The specimen of annealed metal *m* under treatment, if smaller in diameter than to fit just freely the bore of the tube *k*, is kept central in the tube by a very open spiral of brass or aluminum wire of suitable gage. All parts of both devices are worked to a smooth bright surface, as are also the specimens to be

tested. The latter are machined truly cylindrical, with perfectly flat ends normal to the axis.

The screw threads of the compression nut and plug are oiled, and then thoroughly wiped with a clean soft cloth. This leaves sufficient oil for lubrication on the sides of the threads, which are not reached by the cloth (a few mgs. in all). A heavy lubricating oil is used which has been exposed in a shallow vessel to the air of the laboratory for several years, and is believed to have no appreciable vapor tension, and hence does not evaporate. No oil is left on any exposed part.

When weighings are to be made, the device Fig. 2 or 3 with its cylinder of metal to be tested, all wiped perfectly clean, is suspended on the left-hand end of the balance beam by means of its brass hook *k* and a brass wire link depending from the lower pan hook of the balance arm, while the left pan remains, hanging free.

The brass hook and link, every part of the duralumin, the metal under test, and in the case of Fig. 3, the centering wire spiral and steel step *i* are counterpoised on the right-hand pan by a closely equal weight of the same material cut from the same stock and having the same character of surface. This counterpoising even extends to the lubricating oil, a small drop of which is placed in a shallow cavity in the top of this duralumin counterpoise. Under these conditions no correction is required for changing buoyancy of the air due to changing barometric pressure, moisture content or temperature.

The Balance.

Fig. 4 is a plan diagram of the balance and its surroundings. It is mounted in a substantial cabinet of well seasoned and varnished wood *D*, with a glass door *n* hinged at *o*. The cabinet is firmly bolted to a brick wall 40 cm. thick, in a large room of the basement laboratory in which temperature is very steady, rarely varying one degree in 24 hours. The wall to which the cabinet is attached is an inside one equally warm on both sides; and the cabinet is 8 m. from the nearest of the four small windows of the room, which are never opened.

An excellent Becker balance *E* of 200 grams capacity is carefully leveled on the floor of the cabinet. The balance case has the usual

glass sides and ends *p*. A zinc plate *r*, 15 cm. diameter lies on the floor of the balance case under each pan *s*. These plates, and the brass column *t* which supports the balance beam above, are electrically "grounded;" so that when the beam is raised off its agate bearings both pans and their loads, as well as the zinc plates are grounded, thus preventing electrostatic attraction or repulsion between the pans or loads and the floor of the balance case. The usual mechanism for raising and lowering the beam, and for manipulating the velvet-tipped pan checks, is operated from outside the cabinet by simple means not shown.

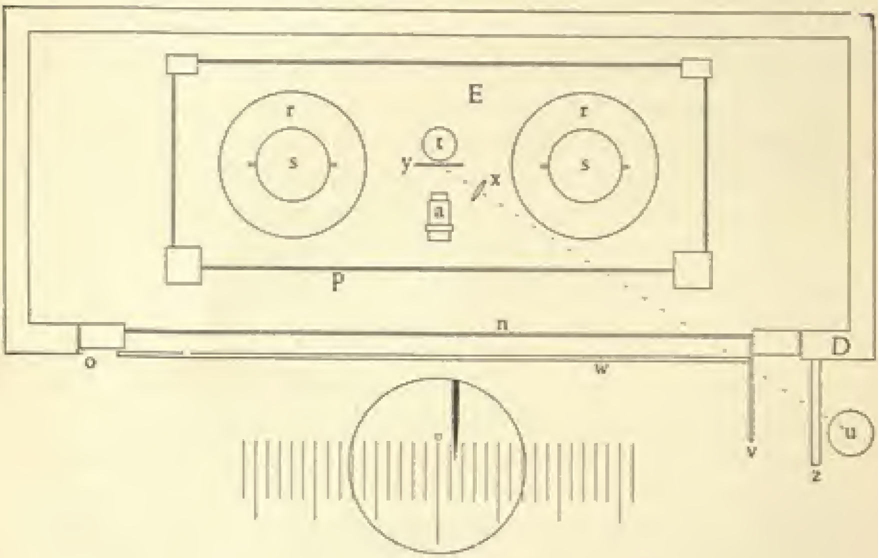

FIG. 4.

A beam of light from the small lamp *u*, restricted by the diaphragms *v* and *w*, is concentrated by a lens *x* on the ivory reading-scale *y*. Most of the heat of the lamp is absorbed by a plate of glass *z* 1 cm. thick, and much of the remaining heat is reflected by the glass doors *n* and *p*. Aside from the small beam of light described above, no light or heat from the lamp gets into the cabinet; and no disturbance from the presence of the lamp has been detected.

A thick screen of cellular paper *w*, attached to the door of the cabinet, serves to keep heat from the observer out of the cabinet;

and through a small horizontal slot in this screen the reading-scale y is viewed, highly magnified by a 5 cm. microscope objective a. The latter is adapted to move forward and backward in guides for focusing.

As the reading-scale provided by the maker of the balance was unfitted for the present purpose, the surface of the ivory tablet was ground away sufficiently to remove all former engraving, polished, and reëngraved with very fine lines .25 mm. apart. This scale was engine divided, so that its lines are equally spaced. The lower end of the beam pointer is ground to a very sharp point and blackened, and swings very close to the scale.

The lower part of Fig. 4 shows the magnified scale and pointer as they appear in the field of the microscope. It is not difficult to read the position of the pointer at the end of its excursion to twentieths of a division of the scale; and by moving the eye of the observer slightly to right or left, all parts of the scale may be read. Of course this involves some parallax; but by keeping the pointer in the center of the field, parallax is always the same in the same part of the scale, and so does not matter.

Obviously, it is essential that the floor of the balance case be kept perfectly level, especially in the line of the beam; and for this purpose a precision level (not shown) is placed on the floor of the case parallel with the front, and a line of sight is so arranged that tangency of one end of the bubble with a hair line on the glass may be maintained without any parallax error. Occasionally a very slight adjustment of level is indicated and made. The necessity for this adjustment arises from the very slow distortional effect of shrinking or swelling of the wood of the cabinet and balance case following changes of moisture content in the air.

The balance is adjusted to a half period of about 18 seconds; and with the largest loads used, 175 to 180 grams, gives a deflection of 9.7 scale divisions for 1 mg. change. For loads as small as 60 grams, the deflection rises to 14 scale divisions for 1 mg. In every case deflection is nearly proportional to change of load, and is taken as a measure of it. And as the usual changes are much less than 1 mg., movement of the rider is not necessary during the many weighings involved in one experiment.

The above indicated sensitiveness is ample for the purpose in hand, and the zero point does not materially drift or wander. Of course the balance might be made several times more sensitive by greatly lengthening the period; but this would necessitate moving the rider, and would also make the weighings unduly tedious.

Method of Weighing.

The compression device Fig. 2 or 3, with the specimen of metal or alloy to be tested, is hung on the left-hand end of the balance beam as above described, while the various items of the counterpoise are placed on the right-hand pan, with the beam rider finally so placed that a right-hand deflection of one or two scale divisions is indicated by the pointer.

After the cabinet and balance case have been left open for some hours, without the lamp *u* or presence of the observer, so that all parts may acquire uniformity of temperature, the cabinet and case are closed, the lamp lighted, the beam and pans lowered onto the agate bearings and excursion limits of the pointer read on the scale and noted.

The first two or three excursions are neglected, and the first reading noted is always to the right. Four excursions each way are noted, constituting a set, and then the beam is raised from the agate and lowered again, and four more right and four left readings are made; and so on until six such sets of readings are noted. This constitutes a group of readings, and the mean value of the six sets is taken as the value of the group.

The reason for making so many "sets" of readings lies in the fact that when the central agate knife-edge is raised and then lowered, it does not always return to *exactly* its former position on its agate plate; so that some of the six sets of readings may differ from each other as much as a tenth of a scale division. But by taking the mean value of six sets, the probable error of a group is reduced to something like one part in forty millions of the total load.

During the next few hours several more groups of readings are made, to note the effect, if any, of the presence of the lighted lamp, or any fortuitous cause of disturbance. Very slight changes are sometimes found, and the mean value of all the groups is taken as

the true zero or rest position of the pointer. The reason why so much care is taken to establish this position is that it forms the basis of comparison for all the subsequent weighings.

Next, the cabinet and balance case are opened, the compression device with its load is unhooked from balance and carried to another room, and its lower nut or plug is clamped in a large bench-vise provided with polished metal false jaws. Then with a 25 cm. adjustable wrench with polished jaws (never used for any other purpose) the upper or compression nut or plug is turned until considerable resistance is felt, and the wrench handle brought to some definite position for future reference. Finally, the device is carried back to and hung on the balance as before, and the case and cabinet are closed, having been opened less than a minute. Everything involved in the compression has been kept scrupulously clean, and the compression device has been handled with felt covered tongs.

Of course the work done in the screw turning and compression above detailed very slightly warms the parts, so that the next weighing, if made shortly after compression, always shows spurious lightness. Hence time must be allowed for dispersion of this heat. Usually, weight becomes substantially constant within an hour after compression, and this interval or more is always allowed. When, however, after several partial screw turnings pressure becomes sufficient to start crushing of the metal, two or *more* hours may be necessary to reach stable conditions, because, doubtless, for a time, there is some spontaneous generation of heat while the metal continues slowly flowing.

Following the first stage of compression and subsequent weighing as above outlined, many more similar compressions and weighings are made until the metal cylinder is permanently shortened. This may take several days. Usually the screw is advanced one sixteenth turn at each step, and note made of the increasing resistance to turning.

In several cases, where the specimen of metal was too large or too hard to be stressed beyond its elastic limit, although very considerable loss of weight was sustained, this loss was wholly and accurately recovered within a few hours after the pressure was relieved; thus inspiring great confidence in the stability of the weighing apparatus.

In a long series of experiments with many metals there has been no evidence whatever of any loss of weight by attrition; nor of gain by oxidation. All specimens of metals and alloys have remained bright without visible tarnish during the time of experimentation with them.

Results.

In a large majority of the many experiments, made with various metals and alloys, however prepared for testing, some loss of weight has attended the application of severe compressive stress. In a few cases a small gain in weight has occurred in the early stages of pressure application, followed by loss at higher pressure.

Lead, bismuth, cadmium, tin, and more slowly zinc, undergo spontaneous annealing and recrystallization at room temperature; and this tends constantly to neutralize the effect of pressure. Zinc is one of the most efficient metals found, when alloyed with a small quantity of certain metals to harden it and prevent spontaneous annealing. Aluminum gives excellent results without hardening.

A very remarkable alloy of zinc 89, aluminum 7, and copper 4 per cent., known as Rosenhain's alloy, behaves in a most unusual way. When melted and quickly cooled, it is very elastic, like tempered steel, and almost as hard. Its fracture is almost white and quite structureless. But when melted and very slowly cooled in the usual manner, its fracture shows some very small crystals in an amorphous matrix.

When thus modified by slow cooling, and subjected to very high pressure, this alloy experiences considerable loss of weight but tends slowly to recover this loss spontaneously, and at the same time shrinks longitudinally and partially relieves the pressure upon it as evidenced by easier turning of the screw. When again high pressure is applied this phenomenon is repeated. When pressure is released, complete recovery of initial weight occurs in a few hours, although the cylinder is permanently shortened. This seems an extreme case of spontaneous annealing or restoration of condition.

An alloy of 40 parts zinc with 60 parts aluminum, melted and slowly cooled in the manner of Fig. 1, experienced rather large loss of weight under high pressure in many steps. Much of the loss was sudden, with partial recovery in next 2 or 3 steps.

An alloy of 95 zinc with 5 aluminum, melted and slowly cooled as above, lost very moderately in weight under pressure, but fully recovered in a few hours after relief of pressure.

Pure zinc, melted and slowly cooled in the usual way, lost weight rather largely and suddenly in the latter stages of compression, accompanied by some noise or "cry" indicating that crushing and permanent deformation was taking place; and at the same time offering increased resistance to turning of the screw. When pressure was released, full recovery of weight occurred within 14 hours. This is another case where, apparently, spontaneous recrystallization restored initial condition notwithstanding permanent distortion.

There is much evidence tending to show that in metals and alloys which do not spontaneously anneal at room temperature, full recovery of lost weight follows release of pressure, *provided* the elastic limit has not been passed; and that greater weight-loss occurs after permanent distortion sets in, but this is not recovered when pressure is released.

Zinc, melted with an equal weight of Rosenhain's alloy, well mixed, cast in an iron mold, remelted and slowly cooled, all as described in connection with Fig. 1, yielded very large weight-loss effects under compression. It did not behave at all like Rosenhain's alloy alone. The composition of this new alloy was approximately zinc 94.5, aluminum 3.5, copper 2 per cent. There can be no doubt of the beneficial hardening effect of the 2 per cent. of copper. The zinc was electrolitic, and nearly pure.

The annealed casting, 1.7 cm. diam., was machined to 1.252 cm. diam., and about 7.35 cm. long. In its final size it weighed 63.5 grams. Compression was made in the tubular device of Fig. 3.

Fig. 5 shows graphically the loss in weight of the alloy at each stage of pressure application. "One turn of screw" means 1.25 mm. (pitch of screw) less elasticity of all parts, which, upon final release, was found to be rather more than one fourth turn. The cylinder was permanently shortened .92 mm. or 1.25 per cent.

It appears highly probable that the sudden and great drop in the curve occurred soon after the elastic limit was passed, and the "yield point" reached. As the writer sees it, this was when considerable motion first took place at the slip-planes between the

crystal grains; and the slip was large because, when once started, it was followed up by the elastic pressure of the parts.

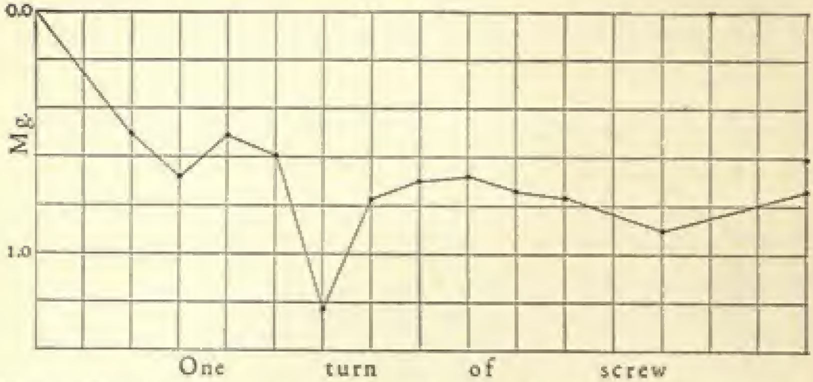

FIG. 5. Loss in weight under compression strain. Zinc 94.5 per cent., aluminum 3.5 per cent., copper 2 per cent. Weight of specimen 63.5 grams.

Subsequent tests of a similar specimen of the alloy in a testing machine, gave 1318 kg. per cm.^{2} for the "yield point," and 2108 kg. per cm.^{2} for a permanent deformation of 1.14 per cent; or 1673 kg. and 2685 kg. respectively for the cross-section of the cylinder of the diagram.

A quite similar, and proportionally quite as large and sudden drop (loss of weight), followed by similar rapid recovery on increase of pressure, occurred with the zinc 40, aluminum 60 per cent. alloy already mentioned. And the same sudden drop occurred also with pure zinc, as noted before.

Returning to Fig. 5: Just what happened in the metal when the next increment of pressure was applied and the curve rose suddenly (recovery of weight), is not so clear. But rapid return toward the condition which prevailed before the slip occurred is indicated. The following steady droop in the curve (loss of weight) for several stations is notable, and will be referred to again in connection with aluminum. The final application of pressure was very large, 3/16 turn, and the curve rose. The dot on the right-hand vertical line of the diagram indicates the point reached several hours after all pressure was removed.

Fig. 6 shows the behavior of aluminum treated like the hardened

zinc last described. The annealed casting was machined to a cylinder 1.6 cm. diam. by 7.15 cm. long, and bored to fit the spindle of compression device Fig. 2. Its weight was 29.7 grams.

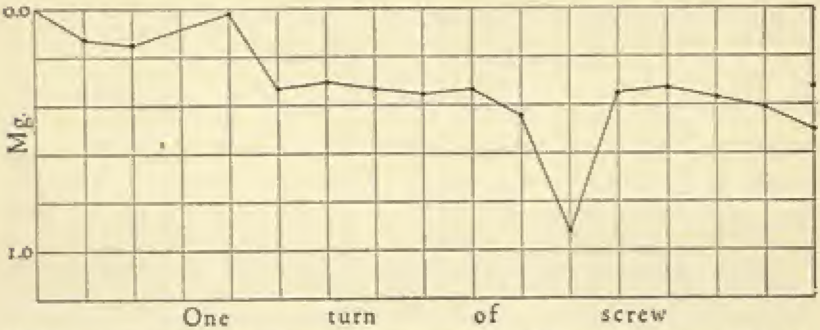

FIG. 6. Loss in weight under compression strain. Aluminum 99 per cent., iron .68 per cent., silicon .32 per cent. Weight of specimen 29.7 grams.

"One turn of screw" here means only .75 mm. (pitch of screw) less elasticity of all parts, which, on final release, was found to be rather more than 7/16 turn. But the first station, in left of diagram, represents 12/16 turn in order that the more interesting parts of the curve may be shown. The remaining 15 divisions of the diagram represent 1/16 turn each.

Between the second and third stations an all night interval of time elapsed and nearly, but not quite, full recovery of weight occurred. Very likely some spontaneous annealing was taking place. The immediately following large drop is thought to indicate the first slip between the crystal grains, followed by nearly stable condition during several increments of pressure. Then a large slip occurred with much loss of weight, and large recovery at the next increment of pressure, just as with the zinc alloy of Fig. 5. Next there follows a steady drooping of the curve, again as in Fig. 5. It is thought these striking resemblances between the curves cannot be accidental. The writer regrets that the aluminum experiment of Fig. 6 was not carried a few steps further. The upper final dot shows recovery following full release of pressure.

It must not be overlooked that the maximum loss of weight by the aluminum (Fig. 6) was much greater in proportion to the weight of metal tested (1/32.350) than in the case of the zinc alloy (1/52.100).

There is the possibility that inertial mass changes when weight changes, and to the same extent. But this is thought to be extremely doubtful.

It has been suggested that the observed loss of weight may possibly be due to escape of occluded gas when the metal is greatly stressed and strained. This would mean expulsion from the zinc alloy of about 1 cc. of gas of air density, or about 11 per cent. of its volume. Half of this would be quickly expelled by a very sm increase of pressure when the slip occurred (Fig. 5). And as appreciable reduction in volume of metal could have taken place, ie gas, if any, prior to its escape, must have been very highly condensed. At the next small increment of pressure a large *absorption* of air (the only gas then present) is indicated (on the gas hypothesis) condensing itself under very great pressure. All of this is quite unbelievable by the writer who therefore regards the gas hypothesis of weight loss wholly untenable.

The writer at present offers no explanation of the weight changes described in this paper; but has in progress a quite different line of experiment which gives promise of shedding much light on the whole subject of mass-weight ratio differences and the associated kinetic theory of gravitation.

The Arcade,
Cleveland.

NOTES ON THE PORTUGUESE INSECTIVOROUS PLANT, *DROSOPHYLLUM LUSITANICUM.*

By JOHN W. HARSHBERGER.

(*Read April 24, 1925.*)

Cognizant of the fact that Charles Darwin received living specimens of the Portuguese insectivorous plant, *Drosophyllum lusitanicum* from the sides of dry hills near Oporto, Portugal through Mr. W. C. Tait, the writer while in Oporto during June 1923 through the courtesy of the assistant American consul, a native Portuguese, secured an introduction to Prof. Gonçalo Sampaio, professor of botany in the University of Oporto, who kindly piloted him to Serra de Valongo on June 21, 1921, from which mountain the living plants studied by Darwin were obtained. The locality is reached easily by automobile (charge 70 escudos) from the center of Oporto.

Darwin ("Insectivorous Plants," edition published by D. Appleton and Company 1875, pages 332–342), has shown that the linear leaves of *Drosophyllum* possess stalked tentacles, which are immobile, and minute almost sessile glands, which do not secrete until they are excited by the absorption of nitrogenous matter. He discovered that the drops of viscid secretion are removed readily from the glands, so that when an insect comes into contact with a drop it can crawl away, but touching other drops, it is smothered finally by the secretion, sinks down on the sessile glands and dies. Darwin found that the secretion is strongly acid before excitation and that small insects, largely Diptera, adhere to the sticky material. Carlos França [1] in "Recherches sur le Drosophyllum lusitanicum Link et Remarques les Plantes Carnivores" with one plate and three figures in the text describes the histology and morphology of this plant with additional information as to its physiology, as related to its microscopic anatomy, but neither Darwin nor França describe the physical conditions and ecologic environment of this suffru-

[1] Archives Portugaises des Sciences Biologiques. Tome I, Fascicule 1, Lisbonne, 1921.

tescent plant. It remains for the writer to complete the general information about *Drosophyllum lusitanicum* by a description of the environmental conditions under which it grows. It is confined to Portugal and Morocco and is found no where else in the world. It is considered a rare plant, although it is found in considerable abundance within its narrow geographic range.

Serra de Valongo is a low mountain range outside of Oporto. The slopes of this mountain are covered with loose, irregular stones scattered over the surface. These stones are non-calcareous and of a quartz-like character, and evidently as the surface is hard, there is a rapid drainage of the water from the surface, rather than seepage, which owing to the presence of loose fragments of rock must be also considerable. (Plate I, Fig. 1). On June 21, 1923, the surface was hard-baked and dry. The association of species on Serra de Valongo was an open one, (Plate II, Figs. 3 and 4), and nearby the maritime pine (*Pinus pinaster*), formed an open forest of low-growing trees (Plate I, Fig. 2). Evidently the association is macchia on non-limestone soils, and the pine associated may be called a maritime pine macchia, according to a paper submitted by the writer to another scientific periodical for publication. As *Thymus caespiticius* is an abundant perennial herb of this macchia (Plate II, Fig. 3), we can use the designation applied to macchia where the thyme is abundant of tomillare from the Spanish word for thyme, tomillo.

Drosophyllum lusitanicum, which has a woody base, long slender fibrous roots, which grow deeply into the crevices of the dry soil, penetrate to where moisture is found, and break off when the plant is collected, grows about a foot tall and is scattered over the surface, a plant here and there (Plate II, Fig. 4). Its linear, tentaculate leaves are crowded with small gnats, which have been captured by the sticky secretion of its tentacles. The plant never grows in dense patches, but scattered, as the photograph reproduced in Plate II, Fig. 4, clearly shows. On June 21st, it was found with flower buds, fully open flowers, unripe and ripe capsules, so that from the ripe fruits mature seeds were collected. The flowers are bright sulphur-yellow in color about an inch to an inch and a half across, when fully expanded, and with convolute aestivation. Ruthless botanical

FIG. 1. Dry sterile tomillares (Macchia with thyme) on Serra de Valongo near Oporto, Portugal, June 21, 1923. This hill is the locality which supplied Charles Darwin with *Drosophyllum lusitanicum.*

FIG. 2. Forest of young maritime pine, *Pinus pinastes*, on Serra de Valongo, near Oporto, Portugal, June 21, 1923.

FIG. 3. *Thymus cæspiticius* in Tomillares Macchia, Serra de Valongo, near Oporto, Portugal, June 21, 1923. The thyme is in the front in prostrate mats in full flower.

FIG. 4. General view of Tomillares (Macchia) with Portuguese Insectivorous Plant, *Drosophyllum lusitanicum*, in foreground, Serra de Valongo, near Oporto, Portugal, June 21, 1923.

collecting would exterminate the plant in a few years from the mountain slopes near Oporto, and it is preserved there, because the soil is too sterile for cultivation.

The species associated with *Drosophyllum lusitanicum* in the macchia on Serra de Valongo collected by the writer, and identified on his return home to America, and which constitute the florula of that Portuguese mountain are arranged alphabetically, as follows: *Agrostis delicatula, Anthemis (Lepidophorum) repanda, Astrocarpus sesamoides, Brachytropis (Polygala) microphylla, Bonjeania (Lotus) hirsuta, Briza maxima, Cistus Clusii, C. monspeliensis, C. salvifolius, Conopodium ramosum, Cotula (Matricaria) aurea, Drosophyllum lusitanicum, Erica cinerea, E. umbellata, Genista hispanica, G. horrida, Genistella tridentata, Helianthemum tuberaria, Pinus pinaster, Rubus ulmifolius, Sedum brevifolium, Spartium strictum, Spergularia radicans, Thymus caespiticius, Tolpis barbata, Trisetum villosum, Tuberaria vulgaris, Ulex europaeus, U. micranthus, U. nanus.*

A few additional species added to the field note book of the writer by Prof. Gonçalo Sampaio are *Avena sulcata* and *Succisa pinnatifida*. The association, or florula, as noted on June 21, 1923, comprised 32 species and more not collected by the writer, or noted by Prof. Sampaio.

The six genera of the family *Droseraceae* are *Dionaea, Aldrovanda, Drosophyllum, Drosera, Byblis* and *Roridula*. *Aldrovanda* is a rootless, swimming, aquatic plant ranging from India to southern France. It has trap-like leaves. *Dionaea* is a North American plant confined to a narrow strip ten miles wide and sixty miles long near Wilmington, eastern North Carolina. Its leaves are remarkable insect traps. There are two species of *Byblis* endemic to Australia and the two species of *Roridula* occur in moors at the Cape, South Africa. The ninety species of *Drosera* generally inhabit bogs and situations with moist soil and their leaves of various forms are provided with sensitive, movable tentacles, the tips of which secrete a sticky fluid, which glistens in the sunlight, hence the common name of these plants, viz., sundew. This brief summary shows that five of the genera of *Droseracere* have more or less specialized leaves with movable leaf blades, or movable tentacles. *Drosophyllum lusitanicum* with unmovable tentacles occurs in a

habitat which is dry, rocky and sterile, quite contrary to the moist habitats of the other genera of the order. The habitat and physiologic pecularities of this insectivorous plant would mark it as a primitive ancestral form with less specialized arrangements for trapping insects. Being a dry land plant is its non-movable tentacles associated with the sterility of soil in which it grows, while the sundews (*Drosera*) growing in a soil with abundance of moisture have irritable tentacles, that move when stimulated by the capture of some insect by the drops of sticky fluid which exude from the tentacular tips? Immovability of tentacles seems pari passu to be associated with sterile soil, active movement of leaves and tentacles with a moist substratum.

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THE MOUNTED SKELETON OF A NEW MESOHIPPUS FROM THE PROTOCERAS BEDS.

By WM. J. SINCLAIR.

(*Read April 25, 1925.*)

So few skeletons of Upper Oligocene fossil horses are known (only two, to the best of my knowledge, having been assembled so far) that no apologies seem necessary for putting on record one of them. The first of the two is the type of *Miohippus intermedius* in the collection of the American Museum of Natural History shown here, for comparison, on Pl. III, Fig. 2, with the kind permission of Professor Osborn.

When Mr. J. B. Hatcher began collecting from the Protoceras channel sandstones of the Upper White River Oligocene, with the Princeton Expedition of 1893, he and Mr. J. A. Murray, Princeton 1894, secured several blocks of this coarse matrix containing the limbs and other bones of a young horse with extremely long feet. The material all belongs to a single individual, No. 10729 Princeton University Geological Museum. The feet were partly worked out, but the rest remained, unprepared, in storage until last summer, when exploration among the blocks revealed enough of the skeleton, including the skull, with the left half of the lower jaw in articulation, to justify assembling the whole in low relief on a plaster panel, with a minimum of reconstruction, as shown in the accompanying photograph, Pl. III, Fig. 1.

The Protoceras sandstones are an unfortunate matrix for the preservation of fossil bones, which although often in abundance, are frequently frail in texture from incomplete petrifaction; may have been considerably abraded previous to fossilization from contact with the coarse stream-transported sand or have undergone subsequent decay from the ease with which the sandstone matrix can be eroded; are, in many cases, disassociated from adjacent parts or in association with the bones of unrelated animals, as a consequence of stream transportation; and, finally, are often distorted by rock

pressure. Our horse has suffered, more or less, from most of these, especially the skull, which lacks practically all of the right side, a difficulty overcome by the method of mounting.

The photograph fails to show clearly the extent to which restoration of missing parts has been practiced. There has been no substitution from other skeletons. The symphysis of the lower jaw with the incisors and canines, part of the ascending ramus, and the back of the skull had weathered away completely and are modeled in plaster. All the cervical vertebræ from the axis backward are lacking, as are also the first six dorsals. Three dorsals and a part of a fourth in continuous series are preserved, and are interpreted as the seventh to tenth. The eleventh dorsal is indicated in outline. Then follows a series of four centra with part of a fifth, all in contact, with a fragment of another dorsal centrum adhering to the first lumbar. This makes a total of seventeen rib-bearing vertebræ, to agree with the formula in the American Museum's skeleton of *Miohippus intermedius* previously referred to. All these dorsals lack spines; and I have reconstructed them following, in general, the proportions indicated in the skeleton just mentioned. The base of the spine of the eighth dorsal has been pushed backward by crushing, overlapping that of the ninth and I have not attempted to separate them, which accounts for the somewhat awkward spacing of the tips of the spines at this point in the column. All six lumbars are represented by centra, but only the fifth has the spine approximately complete, and I have sketched, in outline, the other spines from it. Of the four fused vertebrae in the sacral complex, the last lacks a part of its spine, the remainder being complete. A fifth vertebra, unfused with those preceding, resembles the sacrals in shape and probably belongs with them. Eighteen caudals have been indicated in outline, following the formula in *Miohippus intermedius*. The scapula lacks the anterior margin and but fragments of ribs remain, which have been completed in plaster and indicated in low relief, as of the right side. Although badly damaged by decay, the shaft of the right humerus is complete for length on one side, its left fellow retaining the ends only, with the central part of the shaft completely gone, but readily reconstructible, for length, from the opposite side. The left radius, ulna, and carpus were found in

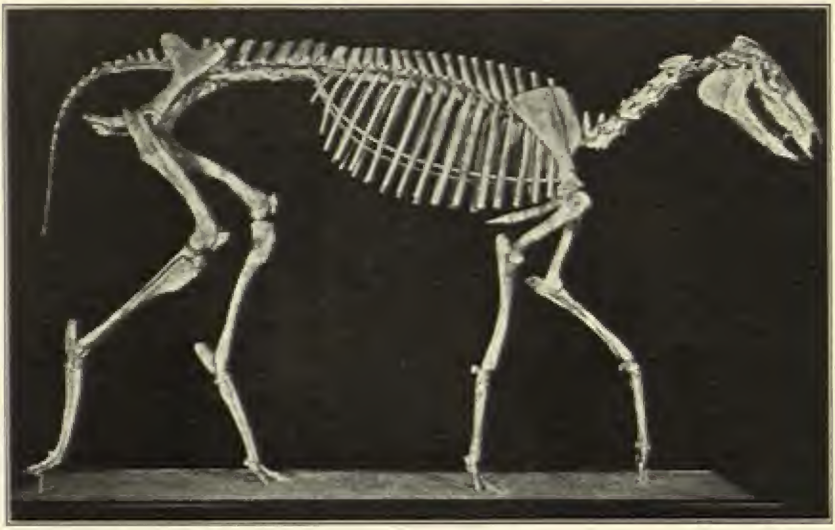

PLATE 5. *Miohippus intermedius* Osborn. Type specimen. Mounted skeleton of the adult animal No. 1196 American Museum of Natural History. Height at shoulder, 25½ inches; at loins, 28 inches.

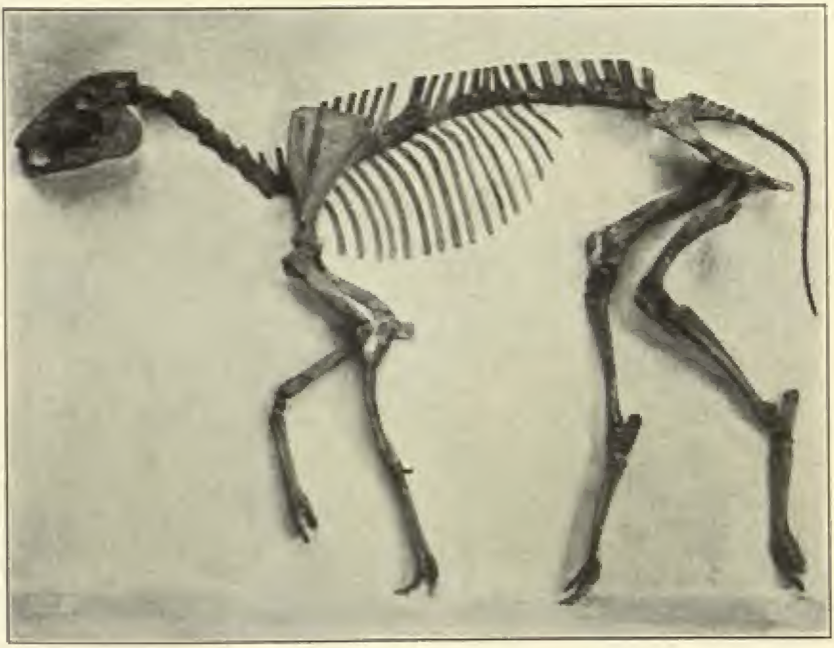

PLATE 6. *Mesohippus grallipes* sp. nov. Type specimen. Mounted skeleton of juvenile animal No. 10729 Princeton University Geological Museum. Height at shoulder 29½ inches; at loins, 33 inches.

articulation and complete except for the trapezium and a part of the radial head. Of the opposite side there remain the distal end of the radius and part of the ulna proximally, and the entire carpus and forefoot except, trapezium, pisiform and digit V. By modeling the left forefoot beyond the proximal portion of the metapodials, also preserved, from its neighbor on the right side, it was possible to mount both fore limbs. For lack of data, the vestigial fifth toe has been omitted from the manus, its presence being indicated by the articular surfaces for its support. No restoration was necessary in the pelvis excepting the ischial tuberosity or in the hind limbs except for a small section of the shaft of the left femur and the entire right patella. In the right fore and both hind feet the position of the metapodials, as found in the matrix, has not been disturbed, except to reset a dislocated distal epiphysis on the median toe of the right hind foot. The phalanges have been shifted from death pose to accord with the positions assigned to the limbs in the mounted skeleton.

In sketching the centra of the missing dorsals, I have tried to approximate their length from those most closely adjacent and have erred, if at all, in getting them too long rather than too short. Also in the neck, my series of cervicals may be too long, but I have tried to be governed here by the relationships between the lengths of the atlas and the other neck vertebræ as seen in *Miohippus intermedius*. Making all due allowance for errors in the length of the vertebral column just indicated, the mounted skeleton shows us the proportions with which we are all familiar in the foal of the modern horse—long legs and short body. A glance at the teeth reveals but one of the permanent series in eruption in either jaw, the first true molar, all the anterior teeth belonging to the milk set. Our fossil was, indeed, a colt, and it is interesting to find the proportions of modern colts appearing among their Upper Oligocene forebears.

In modern horses, according to C. F. Müller ("Anatomie und Physiologie des Pferdes," I, 346), the first true molar appears at the age of six to nine months or somewhat later, and the second toward the end of the second or beginning of the third year. If we are at all justified in reasoning from analogy, the age of our colt at the time of its death would be between these limits, probability favoring

MEASUREMENTS.

	Mesohippus grallipes sp. nov. Type No. 10729 Princeton.	*Mesohippus gra lipes*, referred specimen, No. 10967 Princeton.	*Miohippus validus* Type No. 1218 Am. Museum Nat. Hist.	*Miohippus validus*, referred specimen, No. 10733 Princeton.	*Miohippus intermedius* Type No. 1196 Am. Museum Nat. Hist.	*Miohippus gidleyi* Type No. 1192 Am. Museum Nat. Hist.
Scapula, maximum length	215 mm.	....	....	....	169 mm.	
Humerus, length, head-trochlea	176	....	164 mm. (No. 1218a)*	196 mm.	156	
Radius, length, inner side	187	....	....	207	177	
Ulna, "	233	....	....	244	222	
Pelvis, maximum length, as restored	245	....	....	....	243	
Femur, length including trochanter major	256 ±	....	261 ± / 250.5 ±	....	249	
Tibia, length, exclusive of spine	260 ±	289	....	283	240.5	
Skull, premaxilla to tip of occipital crest, as restored	213	....	....	....	226	
Milk dentition, upper, length	56.5					
" " lower, "	54					
M^1, anteroposterior	15	....	16.5	15	13.5	14.5
" transverse	20	....	21	20	18	19
M_1, anteroposterior	15	....	....	....	14	
Metacarpal III, length	148	....	125 (No. 1218a)*	134.5	128	
1st phalanx, 3d digit, fore, length	20	....	....	....	18.5	

* No. 1218a Am. Mus. Nat. Hist. is a smaller horse, referred by Dr. Matthew to *Miohippus intermedius*.

	Mesohippus grallipes sp. nov. Type No. 10729 Princeton.	*Mesohippus grallipes*, referred specimen, No. 10967 Princeton.	*Miohippus validus* Type No. 1218 Am. Museum Nat. Hist.	*Miohippus validus*, referred specimen, No. 10733 Princeton.	*Miohippus intermedius* Type No. 1196 Am. Museum Nat. Hist.	*Miohippus gidleyi* Type No. 1192 Am. Museum Nat. Hist.
2d phalanx, 3d digit, fore, length at center of side	12.5 mm.	....	....	....	11	
3d phalanx, 3d digit, fore, length on top of hoof, down slope	23	....	....	....	24 (as restored)	
Metatarsal III, cuboidal contact	no	no	yes	yes	yes	yes
" " length, not including keel	180	175	150.5	....	148	154
Metatarsal III, width proximally, maximum	20.5	23	22	23	18	21.5
Metatarsal III, width distally, maximum	27	25.5	27	....	21 (right) 20 (left)	22
Metatarsal II, length, including keel	169	161	142.5	....	140	142
" IV, " on inner side	165	159	145.5	....	139	
1st phalanx, 3d digit, rear, length	23	25.5	21	25	22	22.5
2d phalanx, 3d digit, rear, length at center of side	15.75	16	14	15	14	12.5
3d phalanx, 3d digit, rear, length on top of hoof, down slope	29.75	28	31	33.5	27	27

the former rather than the latter figure, for there is no trace of the second molar, and the first molar is but little worn. It is, however, entirely possible that the expectation of life in these Oligocene horses with short-crowned teeth was much less than in the modern forms, and the eruption of their permanent molars may have been considerably accelerated.

The contrast in proportions of body and limb lengths in juvenile and adult animals is apparent from the photographs. The head in our colt is certainly much shorter relatively than would be true for an adult individual, and would have to elongate considerably in order to accommodate the molars not yet erupted and for which there is no room in the jaws of our juvenile animal, the middle of the first true molar lying immediately beneath the anterior border of the orbit, in front of which is a broad shallow depression accentuated in depth, anteriorly, by crushing. A comparison of the two photographs will also show that I am indebted to the American Museum specimen for various details of pose, for the placing of the scapula with reference to the vertebral centra and for the length of the dorsal spines, but not for the elevation of the back in the lumbar region. The point of attachment for sacrum and ilium is fixed by the articular scar on the latter, and cannot be raised any higher. Perhaps the hind legs might have been straightened more, but the effect of this would have been to raise the back higher in the rear and increase its forward slope. To increase the flexure of the hind limbs did not seem either justifiable or desirable. The scapula might have been set lower with reference to the vertebral column, but I do not think the extension of the fore leg could be increased. In placing the fore limbs in the new mount, I have been influenced by the position given to them in the skeleton of *Miohippus intermedius*, but comparison with the adult should not be pushed too far, for it seems evident from their contrast in size that both animals cannot be referred to the same species and, as will presently appear, belong to different, although closely related, genera.

Comparison of our colt with the various species of White River horses thus far described from the Oreodon and Leptauchenia-Protoceras beds is difficult, because all of them are based on adult dentitions. Those from the Oreodon beds, refigured and described

in Professor Osborn's "Equidæ of the Oligocene, Miocene, and Pliocene of North America, Iconographic Type Revision" are small animals, none of them much in excess of *Mesohippus bairdii* in size. Large horses, equal in size to our colt, are, however, known, but not yet described, from the upper Oreodon beds, as shown by our No. 10967, some femoral fragments a tibia and hind foot of an adult found by Mr. J. B. Hatcher in 1894 in the upper Oreodon beds in Corral Draw, with the central metapodial 175 mm. long and 25.5 mm. transversely at its greatest distal expansion, as compared with 180 mm. of length and 27 mm. greatest distal width for the same element in our colt. No trace of a facet on metatarsal III for articulation with the cuboid appears in either. In our colt, these elements are in contact in the left hind foot, due to a slight shifting of the tarsal bones in the matrix; but on the opposite side, movement was in the reverse direction, the bones are pulled apart, and no cuboidal facet is seen truncating the corner of the metapodial head. The presence of this facet is listed by Professor Osborn ("Iconographic Revision," p. 51) as one of the nine "chief stages of *character genesis* and *evolution* and of *proportional evolution* observed in the fifteen species at present referred to *Miohippus*," and its absence at once consigns our colt, and the large adult from the Oreodon beds just mentioned, to the genus *Mesohippus*, the large, long-footed representatives of which remain unnamed. I, therefore, propose for our colt the specific name *grallipes* (stilt-foot), designating as type the recently mounted skeleton, No. 10729 Princeton University Geological Museum, and basing specific characters on the measurements given in the accompanying table, but especially on the extremely long feet to which the specific name refers, with the central posterior metapodials attaining a length of 180 mm., but with comparatively short phalanges. I would include, provisionally our No. 10967 in the new species and would emphasize the importance of the contact between the cuboid and metatarsal III as a valuable diagnostic character for the separation of *Mesohippus*, in which it does not appear, from the large upper White River horses referred to *Miohippus*, in all of which it has been found, with the sole exception of the new form here described. This large, stilt-footed horse must, therefore, be placed in the genus *Mesohippus*.

Of the remaining eight "stages of *character genesis* and *evolution*" in *Miohippus*, several cannot be checked against our specimen because applicable to adult animals only, and regarding others there may be a difference of opinion as to the extent to which they characterize *Miohippus* to the exclusion of *Mesohippus;* but taking the species of the former as they stand in the "Iconographic Type Revision," the only two from the upper White River which approach our colt in dental measurements are *validus* and *gidleyi*. As already indicated, comparison is limited to $m\frac{1}{1}$, that of the upper series measuring 15 mm. antero-posteriorly by 20 mm. transversely, a little larger in both dimensions than in the type of *gidleyi* and slightly less than in the type of *validus*, No. 1218 American Museum, but agreeing exactly with the measurements of this tooth in an adult skull in the Princeton collection (No. 10733) also from the Protoceras beds, from one of the lower channel deposits, collected the same year as the colt skeleton and from the same general area and horizon in the drainage basin of Cottonwood Creek, in what is now Washington County, South Dakota, which was identified by Professor Osborn in 1904 as *Miohippus validus* and used by him in defining the species. So far as I can see there is nothing about m^1 in either the colt or this adult specimen to serve as a basis for the separation of *Mesohippus* from *Miohippus*. Associated with this skull of *validus* are several limb and foot bones, including a median metapodial of the forefoot and the proximal end of the similar element in the left hind foot which were still in the matrix when Professor Osborn's studies were made. Measurements of these are given in the table where some of them are seen to approximate the size of our No. 10967, while others exceed the lengths of corresponding parts in the colt skeleton; but the anterior metapodial, although adult, is considerably shorter than in the latter, and the fragment of the corresponding element in the hind foot carries a prominent cuboidal facet. The type of *validus* in the American Museum, their No. 1218, is associated with a hind foot in which the central metapodial is only 150 mm. long, in contrast with 180 mm. in our colt, although agreeing with it in distal width, and has the cuboidal contact developed. Included therewith is a humerus and the central metapodial of a fore foot, designated 1218*a*, and from its size referred by Dr. Matthew to *Miohippus*

intermedius (see table of measurements under 1218*a*). In a matrix of fluviatile origin like the Protoceras sandstone, there is always a chance that bones of unrelated animals may occur together; and in fact foot bones of a rhinoceros and an oreodont are included with our No. 10733; but there is no reason to believe that the central metapodial of the fore foot found with it, of which the dimensions are given in the table of measurements, belongs in this case also to a smaller horse.

The foot associated with the type of *Miohippus gidleyi*, No. 1192 American Museum, is shorter and not quite as heavily built as in our colt, from which it also differs in the presence of the cuboidal contact. This is a progressive character reaching a maximum of development in *Equus*, and it is interesting to note its contemporaneity with conservative large, long-footed forms, first known thus far in the Upper Oreodon beds, but persisting into the higher Protoceras levels and perhaps constituting the stock from which *Miohippus* originated. The extent to which the cuboidal contact is subject to individual variation is unknown, but such variation might be anticipated among animals "passing from one genus to the next" (Osborn, "Iconographic Revision," p. 51).

From stilt-walking horses of the genus *Kolobatippus* our colt is readily distinguishable by the separation of the metaloph and ectoloph in the molars and the absence of the cuboidal facet on the third metatarsal. The orbit is still wide open posteriorly, so there need be no occasion for confusing it with short-crowned representatives of *Parahippus*.

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THE IMPORTANCE OF FIELD-WORK IN THE STUDY OF CLIMATES.

By ROBERT DeC. WARD.

(*Read April 24, 1925.*)

The Three Stages in the Presentation of a Climatic Description.

Classifying very broadly it may be said that there are three stages, or methods of presentation, in the discussion of the climate of any given locality or region. Stating these in the inverse order of their value, they are as follows: First, the bare conventional numerical tabulation of the standard climatic data. Second, the addition of descriptive accounts of the weather types and of their relations to man, written by people who possess keen powers of observation and who know the conditions of which they write. Third, and most effective of all, is the personal experience of the weather and climate which can be gained only by visiting the region in question. Each of these three methods of treatment has its essential merits. All three deserve adequate attention on the part of teachers and students of climatology.

I. *The Purely Statistical Climatic Statement.*

Much emphasis has been laid, and rightly so, upon the absolute necessity, in climatological studies, of systematic observations, carefully checked, punctually recorded, and extending throughout many years, of properly exposed standard meteorological instruments. The standard conventional description of a climate is given when such numerical data, summarized and compared by well-known methods, are tabulated in proper form. Upon such data the scientific study of the world's climates must always be based. They are the foundation of climatology. Without them everything remains vague; no real comparison of climates is possible; no detailed investigation of climate in relation to health, to crops, to industry, can be undertaken. Yet any one who has read such "stock" summaries, hundreds of which are included in books of

reference, encyclopaedias and other publications which deal with the geographic conditions of all parts of the world, and especially any one who has tried to teach climatology by means of these summaries, knows that they are merely skeletons, and, like any other collections of bones, are hard and very dry. Publications consisting wholly of tabulated data concerning the climate of any locality—and the mail brings to the climatologist's desk many such, of large size and of great weight—however carefully the original observations were made; however laboriously and critically the summaries were compiled; however essential such purely numerical and statistical sub structures are, cannot fail to be lifeless and imperfect to him who seeks a vivid, interesting and complete picture of the climate of the region considered. Something more is needed than the standard climatic summaries.

II. *The Addition of Vivid Description of Weather Types and of Climatic Controls, Based on Published Accounts.*

An indispensable addition to any mere tabulation of data is a carefully selected series of clean-cut, pointed, vivid descriptions, emphasizing the living aspects of weather and climate, and written by persons who have lived in the district whose climate is being considered, or who have at least travelled through it. The dry bones of the skeleton of numerical data are not enough. Flesh and blood must be present if there is to be any vitality. In any discussion of the weather and climate of the different parts of the world, the constant endeavor should be to bring out and to emphasize in every possible way the human or economic relations of climate. In the effort to present this life-like picture every possible reliable source of information should be drawn upon. Hann's master-work, the *Handbuch der Klimatologie*, is a splendid illustration of what can be done in the way of amplifying, enriching, and enlivening the mere dry tabulation of numerical data. In this monumental work—the climatologists' absolutely indispensable *vade mecum*—the climatic descriptions are not only made complete, but they are made fundamentally interesting, by the addition of vivid descriptions of weather types; by frequent reference to the effects of climate upon vegetation, upon crops, and upon human activities, and by well-chosen

quotations from the writings of residents and of travellers who are familiar with the climates concerning which they have written. Climatic descriptions would gain immensely in value and interest were such a broad view of climate always in the mind of the writer. Climatography, which is descriptive climatology, is more and more becoming anthropo-climatology, just as geography has of late years increasingly become anthropo-geography. The service of man, and not merely the collection and investigation of scientific facts, is the object of the world's scientific endeavor along all lines. The study of the life-reactions of climate is the most important subject for the climatologist. His discoveries in this direction are his greatest contributions to the advancement of science. Practical or applied, as distinguished from pure or theoretical, climatology, concerns itself with the relations of the climatic elements to all forms of life—human, animal and plant. The aim is to discuss the value of the climatic factor in the distribution, characteristics and habits of man, and of the animals and plants upon which his life, directly or indirectly, depends. It deals with such subjects as the control of climate over crops, types of agriculture, dwellings, clothing, customs, occupations, travel and transportation, industries, habitability; with acclimatization; with the relations of climate and health, and with an almost endless series of similar immediately practical problems.

III. *Supplementing the Climatic Study by Travel.*

If the teacher or student of climatology is to have a clear understanding of the world's climates he cannot be satisfied with the published numerical data, no matter how accurate these may be, or how carefully they have been discussed. Nor can he be satisfied with the descriptions given by others who know the places of which they write. The climatologist, no less than the geologist and the geographer, should travel. For between the tabulated data on the page of some climatological report, or the account written by some one else, and actually experiencing the climate itself and observing its effects, there is a difference as great as that between reading a description of a glacier and seeing and climbing over a glacier. However well a teacher may know his text-books, he can never enjoy

the sense of personal acquaintance with other climatic conditions than his own unless he has had the opportunity of observing these conditions for himself. Field-work is essential in climatology. The climatologist needs to visit as many parts of the world as possible in order that he may himself become familiar with the various weather types and climatic controls. In this way, and in no other, can climatic descriptions become really alive, and can a teacher of climatology do his best work. Field-work of the kind here suggested can be done by any one well equipped by previous study who has the good fortune to travel. It is a step in meteorological education whose value cannot be overestimated. Of the truth of this assertion the writer has, in his own experience, had abundant proof.

The natural objection that it is impossible for one person, whether because of lack of time or for financial reasons, to make any adequate field-study of this sort because of the immense variety of different weather types and of climates the world over, is to a certain degree a valid one. But it should be remembered that climates are, as a whole, more alike than they are unlike, and that similar natural regions scattered over the world have similar climatic conditions and similar climatic responses. A personal knowledge, gained by a visit to one such natural region, may in a general way, serve to illustrate the conditions of climate, vegetation, and human life in similar natural regions situated elsewhere.

A traveller who is interested in such field-work and is something more than a mere globe-trotter, can even when passing rapidly through a country by train or by automobile, and still better when moving more slowly on horseback or on foot, observe obvious conditions which will give him a vivid impression of the larger facts of climate and of their controls over man and his activities. Such field-work need not be instrumental. It has been termed by the writer a series of climatic "snap-shots." The impressions thus gained are inevitably superficial, but taken together they constitute a sort of moving picture, as much more vivid than the tabulated data of climate as the real glacier is more vivid than printed descriptions of it. Occasional stops for a nearer view of the country and its people give greater detail, and hence greater accuracy, than

can be secured by observations from the window of a train or from a speeding automobile. Yet there are certain advantages even in a rapid journey, for the climatic contrasts are then sharply emphasized; the "snap-shots" are very clear and instructive.

Simple non-instrumental car-window observations of the kind here suggested add greatly to the interest of a journey, even if only a short one through well-known country. When made with some care in a little-known region, such snap-shots are naturally more instructive and valuable. The writer has long felt that what he has termed "car-window climatology"—perhaps better nowadays "automobile climatology"—deserves far more attention than it has received. In his own experience, when travelling in South America, for example, under conditions which usually made it impossible to carry an instrumental equipment, it was feasible when journeying on horseback, on the Brazilian "trolley," or on the train, to collect facts which added greatly to his own understanding of the climate of the region; made the trips alive and interesting, and helped to hasten the passage of many weary hours. These snap-shot observations it has even seemed worth while to publish for the benefit of those whose acquaintance with Southern Brazil has been more distant than that of the writer.

For the benefit of any who may be interested in making simple non-instrumental observations of weather and climate during their travels, a few suggestions as to such snap-shot studies may here be made. Vegetation furnishes a general criterion in regard to temperature and rainfall. When trees are seen to have shed their leaves we infer a season of cold, or it may be of drought. The occurrence of frost, or of a thin skim of ice in the early morning, gives evidence of nocturnal temperatures below freezing. Frost of varying degrees of severity, and ice of different thicknesses, give general indication of the amount of cold below the freezing point. A rise of temperature above freezing may be noted when thawing is observed, especially in cloudy weather. The altitude reached by killing frosts on the sides of hills may also easily be observed by the effects on vegetation. Wind velocity may be reasonably accurately estimated, after a little practice, by noting the effect of the wind in blowing trees, or in producing waves of different sizes in lakes or on rivers. High

velocities are evidenced by destructive effects in blowing down trees, or doing other damage. The prevailing wind direction can usually be quite well determined by observing the slant of wind-blown trees, which in many places serve as excellent wind-vanes, or again, by taking note of the effects of wave-action on the leeward side of a lake or pond. The direction of rainy or of snow-bearing winds records itself by wetting one side of trees or buildings. Vegetation on mountain slopes often indicates the direction from which the damper winds blow. Whether or not hail, or snow, or sleet, or gales, or heavy rains, or fog, occur in a region is observable, so far as the period of his own visit is concerned, by any traveller. Forest and prairie fires indicate droughts, or dry seasons. Tornadoes and gales may be detected many years after their occurrence by the damage which they did to trees. Whether or not a river is subject to floods may often be determined by such hurried observations as can be made from a car window, by noting the mud deposited by former floods on the trunks of trees, or by seeing the banks and neighboring fields actually overflowed. The condition of roads, whether dusty or muddy, indicates in a way the occurrence, or lack, of recent rains.

The foregoing list is merely intended to suggest a few of the many simple non-instrumental observations which an interested traveller may easily make on his journeys. If he once begins, he will soon find that every day opens up new possibilities. He will rejoice in the sense of discovery. He will find his trip growing in interest from day to day. He will come home an enthusiastic field-worker in climatology.

Field-work in Climatology on the Lewis and Clark Expedition.

The Journals of the famous Lewis and Clark Expedition "to the sources of the Missouri, across the Rocky Mountains, and down the Columbia River to the Pacific in 1804–06" are an excellent example of the value of such field-work as has here been advocated in giving a clear and vivid picture of many of the striking climatic characteristics of an unknown country. These observations, it should be remembered, were made during a hurried reconnaissance trip, and amid great hardships and dangers.

The leader of the Expedition was charged by the President with

reporting upon many subjects in addition to the climatic conditions.[1] In spite of the many difficulties of the journey, and with the use, for part of the time, of only one instrument—a thermometer, which was unfortunately broken before the end of the trip—the observing eye of Captain Lewis noted a great variety of meteorological and climatic conditions, and his vivid descriptions of what he saw and recorded constitute even today, when abundant accurate data are available, a by no means insignificant historical contribution to our knowledge of the climatology of the western United States. No one can read the Journals without being impressed by the keenness of Captain Lewis's powers of observation and by his devotion to his task. Most of the essential atmospheric phenomena and conditions were clearly noted. To give any adequate summary of the numerous and varied observations included in the "Journals" would be beyond the scope of the present discussion. Reference can be made to only a few. The strength of the prevailing southerly winds of the summer over the northern Plains is attested by the fact that they blew the sand from sand-bars and river banks ("the winds blow with astonishing violence in this open country"). Later instrumental records have made clear that these velocities are distinctly high, comparable with those along the seaboard, but no more striking illustration of the strength of the winds over the open Plains has ever been given than Captain Lewis's description of the time when one of his boats, which was being transported on wheels, was blown along by the wind, the boat's sails being set. Surely this story emphasizes the analogy between the winds of the ocean and the winds of the Plains. Both sweep over a surface of little friction. Both in consequence attain high velocities.

The frequent mention of rain in May and June calls attention to the economic importance of the late spring and early summer rainfall maximum—the so-called "Missouri Type"—in relation to the great staple cereal crops of the Plains. The fact did not escape the watchful eye of Captain Lewis that the rainfall of the warmer

[1] President Jefferson instructed Captain Lewis to report upon climatic phenomena as follows: "Climate, as characterized by the thermometer, by the proportion of rainy, cloudy, and clear days; by lightning, hail, snow, ice, by the access and recess of frost, by the winds prevailing at different seasons; the dates at which particular plants put forth, or lose their flower or leaf; times of appearance of particular birds, reptiles or insects."

months over the region which he crossed is essentially spasmodic and "patchy" in character, *i.e.*, of the thunderstorm type, as contrasted with the more general and widespread rains of the large storms which characterize the winter months of the country as a whole. The observation that there is "very little rain or snow either winter or summer" is sufficient emphasis on the general decrease in precipitation west of the Mississippi River, which is so marked a feature on the mean annual rainfall maps of the United States. Captain Lewis paid particular attention to thunderstorms in which, probably because of their frequency, he seems to have been much interested. His remark (April 1, 1805), "I have observed that all thunder clouds in the western part of the continent proceed from the westerly quarter, as they do in the Atlantic states," is probably the first specific mention of this important meteorological fact. On May 18, 1805, the record states: "We have had scarcely any thunder and lightning; the clouds are generally white, and accompanied by wind only." This we may take to indicate the many "dry" thunderstorms of the Great Plains, which, because of lack of sufficient moisture in the air, do not reach the stage of rain production, or, if rain does fall, it is often evaporated before reaching the ground. Careful measurements were made of the sizes of hailstones, which, on June 27, 1805, were as large as pigeons' eggs, and on July 6, 1805, were about the size of musket balls. On the former occasion several of the men were knocked down and bruised; some got under the canoe for protection, and others covered their heads.

"The air is remarkably dry and pure in this open country. . . . The atmosphere is more transparent than I ever observed it in any country through which I have passed" wrote Captain Lewis, thus directing attention to one of the great climatic advantages of the northwestern interior. The rapid evaporation was often observed. Thus (Sept. 23, 1804) on one occasion "in thirty-six hours two spoonfuls of water evaporated in a saucer," and elsewhere in the "Journals" the rapidity with which Captain Lewis's ink dried up was recorded, as furnishing a good measure of the dryness of the air. How few travellers would use their ink wells as evaporation gauges! The thickness of ice frozen in a day is often recorded. On Oct. 18, 1804, water in vessels exposed to the air was frozen, as was "the clay

near the water edge." The occurrence of nocturnal radiation fogs; the prevalence of cold northwesterly winds in the colder months (as contrasted with the warm southerly and southeasterly winds of summer); the depth of snowfall; the appearance of haloes and other optical phenomena; the coming of rains with northwesterly winds—this being a condition not very common in the eastern United States but occurring more frequently in the west—these are a few of the many instructive observations which may be picked out in a haphazard way from the very rich meteorological harvest in the "Journals."

The winter was spent by the Lewis and Clark Expedition on the Pacific coast at the mouth of the Columbia River. This gave Captain Lewis abundant opportunity to observe the climatic peculiarities of that region, and to contrast them with those with which he had become familiar in the east. "The loss of my thermometer I most sincerely regret," he wrote on Jan. 3, 1806. "I am confident that the climate here is much warmer than in the same parallel of latitude on the Atlantic Ocean, though how many degrees it is now out of my power to determine." A few days later he wrote: "Weather perfectly temperate. I never experienced a winter so warm as the present has been." Note is made of the fact that the Coast Indians wore and needed less clothing than those east of the mountains. Clouds and heavy rains and gales—much changeable stormy weather and very little sunshine—made such an impression that Captain Lewis wrote: "The vicissitudes of the weather happen two, three or more times in half a day." On Jan. 28, 1806, a vessel of water was exposed in order that the thickness of ice might be measured. Unfortunately, the water was only two inches deep and it froze to the bottom. "How much more it might have frozen had the vessel been deeper is therefore out of my power to decide," was Captain Lewis's interesting and critical comment. It is clearly stated that the winds from the land were clear and cold, while those blowing obliquely along the coast, or off the ocean, brought warm, damp, cloudy and rainy weather. A significant climatic control on the Pacific coast thus received early and explicit recognition.

Few travellers, especially those who make hurried journeys

through little-known territory, can hope to bring back as clear, vivid and accurate a picture of the climatic conditions as did the famous Lewis and Clark Expedition. But the record of that Expedition may well serve as an inspiration and as a model for those who are resolved, by undertaking climatological field-work, to add to the interest of their journeys and at the same time to gain for themselves a more complete and a more vivid picture of the climates of the countries through which they pass.

The Use of Photographs or of Lantern Slides in the Study of Climates.

If such climatological field-work as has here been suggested is out of the question, photographs and lantern slides make a reasonably satisfactory substitute. In these days of innumerable photographs, both professional and amateur, from all parts of the world, and of the almost universal use of the stereopticon for teaching purposes, a vivid and instructive picture can easily be given by means of carefully selected views illustrating the varied aspects of climate and of man's relation to his climatic environment, *e.g.*, natural vegetation; planted crops and methods of cultivation and of harvesting; irrigation practice; dwellings; clothing; means of travel and transportation; industries, and the like. In fact, the climates of the whole world may in this way be brought into the class room, without the time, expense and annoyance of travel in little-known regions.

It has been the writer's task during the past twenty-five years to give considerable numbers of students, both undergraduate and graduate, instruction in the climatology of all parts of the world. These students have varied greatly in their interest in the subject. There have been those who, from the start, had an earnest desire to master what they were studying, having in mind the professional pursuit of medicine, or of botany, or of geography. There have also been plenty of others, seeking merely an additional course or two in order to fulfil the requirements for their degree. The teacher's business has been to interest all of these men, and women, and in this endeavor every effort has been made to make the subject live, compelling, and vitally interesting. In this task it has been found that the use of lantern slides has been of very great assistance.

From the large number of carefully selected slides (over 15,000) in the Gardner Collection of the Department of Geology and Geography of Harvard University, the writer has chosen several sets, numbering several hundred slides in all, to illustrate the climates of the world's continents and islands. These illustrations are used near the end of each course, when the students have become familiar with the essential facts of climate as shown by the usual numerical data, and have also had opportunity to read many published descriptions of the weather types and of the relations of climate and man. The slides are arranged as cross-sections of the country concerned. Thus, the increasingly continental characteristics as one travels from coast to interior are shown by slides which start with views on the coast, and are followed by pictures taken farther and farther inland. The effect of latitude is illustrated by views arranged from south to north. Altitude controls are emphasized by pictures assembled in proper order from lowlands and valleys up mountain slopes, ending, when possible, with views taken on the mountain summits themselves. It thus becomes possible to give the class a vivid idea of all varieties of climate and climatic responses, and the result is a far clearer conception of what climate really is, and what it does.

In conclusion, brief reference may be made to the method of illustration used in the case of the United States. Three sets of slides have been selected, illustrating three east-and-west cross-sections across the continent, thus emphasizing not only the contrasts between marine and continental climates but also the effects of altitude and of latitude. One of these cross-sections runs across the southern tier of States, from Florida to Southern California. Another starts on the central Pacific coast and crosses the country to the central Atlantic coast. The third starts in New England and crossing the northern tier of States ends on the north Pacific coast. In order still further to curtail the present discussion, these three sets of slides have been "telescoped" into two sets, and the number of views in each set has been reduced by three-quarters. The series as now before us is intended to give a very hasty cross-section from Florida to Southern California; then up the Pacific coast, and back across the northern tier of States to the New England coast. It is a

series of climatic snap-shots—an illustration of the study of climate and of its effects through a car-window.

Starting on the Florida coast, with palmettoes waving in the soft trade winds and with a thought of the mild semi-tropical winters which bring thousands of health and pleasure seekers to that far-famed peninsula, we pass through orange groves on to the cotton region of the north Gulf coast States, with their picturesque negro laborers and a memory of the historical significance of the slaves of past years, imported to work under climatic conditions which the white inhabitants found unsuited to their own comfort or health. A view of flooded bottom-lands along the Mississippi brings to mind the heavy warm rains and melting snows of late winter and early spring to which such floods are usually due. The sugar cane fields of Louisiana once more emphasize the high temperatures and near-tropical characteristics of our Gulf coast climates. The occasional visitation of the Gulf coast by a West Indian hurricane is vividly brought to mind by a view of Galveston after the famous Galveston storm of 1900. We then pass quickly westward, across the broad Texas plains, with abundant evidence of increasing aridity; New Mexico, with its "deserts" and sage brush and wide-open spaces; note the flat roofs of Santa Fé, designed for a climate with little rainfall; are struck by the tree growth on the plateaus and mountains of Arizona, the response to the "lakes" of rainfall at the higher elevations in contrast with the arid lowlands. A view of the San Carlos dam emphasizes the need of irrigation, and of the importance of the mountains in producing sufficient precipitation to make the huge dams and deep reservoirs possible. Tucson, with its irrigated fields, is an illustration of man's conquest over Nature in the Arizona desert.

Reaching southern California, the vineyards and the orange groves emphasize the enormous economic advantages of the sub-tropical climate of the southern Pacific coast, and the importance of the water-supply which comes from the Sierra Nevada Mountains. The coal baskets, or oil stoves, placed at regular intervals throughout the orange groves, show that frost is an occasional, and much dreaded, visitor even in those balmy latitudes. A group of pictures taken along the Southern Pacific line across the Sierras between

central California and Nevada furnishes a striking illustration of the great depth of the winter snowfall—"the life-blood of California"—and a view of the famous forty miles of snowsheds along the railroad shows how man has had to struggle to keep his means of transportation in operation through the long winter. The famous "sea of fog" as seen from Mt. Tamalpais, north of San Francisco, suggests the favorable conditions for fog formation along that coast, with the dangers to navigation which result therefrom. Farther north a view of Paradise Inn on Mt. Rainier, almost buried under snow in winter, indicates the heavy precipitation which prevails all along the Pacific coast mountain barrier. A bit of beautiful scenery along the Cascades of the Columbia River, with the rushing waters and the tree-clad slopes, serves to remind us of the wealth of lumber which Nature has provided in the mild and rainy climate of Oregon and Washington.

Eastward again our journey takes us, across the dry-farming wheat country of eastern Washington; the sage-brush of the lava plateau of the Snake River in Idaho, with a glimpse at the dark forests in the Rocky Mountains in Montana, and then on through the fertile plains of the Red River valley in North Dakota, where rainfall is once again sufficient for the cultivation of the great "bonanza" wheat crops. Then on eastward across great stretches of farming country, with hospitable houses, and ample barns, and varied crops, and many groves of trees. A glimpse into a secluded Adirondack valley, with its forests and its cleared lands, makes it easy to see why that picturesque region is so sought after by summer vacationists. A passing glance at the mills along the Merrimac River at Lowell, Mass., recalls the early industrial development where water-power was easily accessible in New England, and where the natural atmospheric humidity was favorable for cotton spinning. Then follow in rapid succession a typical winter view of New England, with its snow-covered hills, rough stone walls, and a horse-drawn sleigh on a picturesque country road; a gnarled, stunted, wind-blown tree close to the sea, struggling for life against heavy odds; finally, the story of severe gales and a dangerous coast told in the concluding picture of a wrecked schooner, with the brave patrolmen of the United States Coast Guard at their heroic task of saving the lives of the crew.

Such a cross-section of our varied climates, with their many reactions on human life and activity, never fails to impress the minds of even the dullest and least interested student. It gives him a vivid picture which no mere tabulation of climatic data, and no descriptions written by others, can ever give. It brings to him a realization of the supreme importance of his climatic environment in the everyday life and activities of man.

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NEXT STEPS IN RAILROAD CONSOLIDATION.

By EMORY R. JOHNSON, Ph.D., Sc.D.

(Read April 23, 1925.)

Two practical and pressing questions have arisen in connection with the consolidation of railroads as provided for in the Transportation Act of 1920. That Act of Congress authorized the consolidation of railroads by relieving the railroads from the restraints of the anti-trust laws of the federal government and the several states and by permitting railroads to consolidate with the approval of the Interstate Commerce Commission. Two methods of consolidation were made possible by the law, one method being the acquisition of the control by one railroad of one or more other lines by purchase or lease, the several companies to retain their corporate existence and continue to operate as separate companies. This is called incomplete consolidation. Complete consolidation was provided for by authorizing the Interstate Commerce Commission to approve of the merging of several railroad companies into a single corporation, the companies merged to go out of existence, a single new company to take the place of those brought together, the securities of the new company not to exceed the aggregate value of the properties merged. Complete consolidations were to be authorized by the Commission only after the Commission had worked out and published a definite plan of grouping of all the railroads in the United States. Each individual complete merger is by the law required to be in accordance with the general plan of grouping decided upon by the Commission. This plan of grouping, however, may be modified from time to time by the Commission to meet the changing conditions.

Consolidations are to be by voluntary act of the carriers. The bill passed by the Senate in December 1919 provided for compulsory consolidation after a period of seven years. This feature of the Senate bill, however, was not acceptable to the House and did not become a part of the Act of 1920.

The country has now had five years' experience under the Act of

1920, and the question has naturally arisen as to whether consolidations will be accomplished by voluntary action of the railroads and whether it was wise for Congress to stipulate that complete consolidations should be in harmony with a general plan of grouping of the railroads of the country worked out in advance of actual consolidations.

The reasons in support of voluntary consolidation have been strengthened rather than weakened by the experience gained during the past five years. It is becoming more and more evident that the ultimate consolidation of American railroads into a limited number of large permanent systems of relatively equal strength must come about by a voluntary process. For many years, indeed for half a century, railroad grouping has been going on in response to the impulses and influences that determine the financiering plans of individuals and corporations desirous of accomplishing as large results as possible. If the government does not place too great obstacles in the way, the process of grouping of American railroads will continue by voluntary action of ambitious men and corporations. The process will have to go on for many years, perhaps two decades or more, before the consolidation will be completed; but, if allowed to continue, the ultimate grouping of railroads will be brought about in the natural and most economical method.

Probably the most serious objection to the adoption of compulsory consolidation of railroads by mandate of the government would be that the owners of the securities of every railroad would hold their securities until they had been valued by the government. The security owners would naturally expect to receive a higher price for their holdings if their properties were taken away from them by condemnation proceedings. The consolidation of railroads by the ordinary financial methods that bring about voluntary grouping would thus be hindered rather than promoted. It will be the wiser policy for the government to adhere at least for the present to the policy of voluntary consolidation of railroads.

Although it is now more than five years since the Act of 1920 became a law the Interstate Commerce Commission has not promulgated a plan of grouping of the railroads, and thus no complete consolidations have been worked out. Such consolidations as

have been accomplished have been the so-called incomplete ones possible under the provisions of the statute providing for such mergers with the approval of the Interstate Commerce Commission. There has also been one very large consolidation, that of the Nickel Plate, worked out under state laws, only the financial features of that merger having been considered by the Interstate Commission. This consolidation is leasing the Erie, the Pere Marquette, and the Chesapeake and Ohio, and these leases require the approval of the Interstate Commerce Commission.

It is coming to be the opinion of those best qualified to judge, not only railroad officials and other students of the question, but also members of the Interstate Commerce Commission, that the Act of 1920 in requiring individual complete consolidations to be in accord with a general plan prescribed in advance will be a hindrance to the actual grouping of railroads by voluntary process, because the owners of individual properties will hold out for a maximum price, in view of the fact that the Commission has stated that a particular property may be merged only with other properties designated as belonging to a particular group. The effect of prescribing a general plan in advance of consolidation will be to increase the difficulties and the expense of bringing about railroad mergers through ordinary financial methods. Railroad securities will command a price in the market determined, not alone by economic or financial forces, but also by government action.

Doubtless it is because the Commission realizes that the promulgation of a final or definite plan of grouping of the railroads would tend to check voluntary consolidation that the Commission has withheld the issuance of an order setting forth its findings as to a general plan of railroad consolidation. The Interstate Commerce Commission is in favor of amending the Act of 1920 so as to enable the Commission to act upon individual requests for consolidation without reference to a prescribed plan of grouping; and if the Commission is permitted to do this it will be able to act in accordance with the facts of each case as they present themselves at the time an application is made.

In working out voluntary consolidations railway financiers have encountered numerous obstacles imposed by state laws. The Act of

1920 removed only one of those obstacles, that of the anti-trust laws of the states. The question has arisen whether it would be possible and advisable for the federal government to supplement the consolidation provisions of the Act of 1920 by a law so framed as to eliminate or minimize (if elimination is impossible) the obstacles to or prohibitions of railway consolidations now contained in state laws. The drafting of such a federal statute would involve difficult legal questions concerning the relation of federal and state powers, and the subject is too difficult for me to attempt to discuss in detail. It is a subject to which the best legal minds of the country should give careful consideration.

One obstacle to voluntary consolidation has been encountered that could probably be dealt with successfully by federal statute. In some of the mergers now being worked out by the purchase by one railroad of the securities of other railroads, the purchasing company has found, not unnaturally, that the minority stockholders have held out for high prices. Speculators have even acquired minority holdings in order to demand an extortionate price for their securities. The Chairman of the House Committee on Interstate Commerce at the last session of Congress, Mr. Winslow of Massachusetts (who, I am sorry to say, has retired from Congress), introduced a bill, one feature of which provided for the government appraisal of the securities of minority interests and the acquisition by the purchasing company of the holdings of such interests at the valuation fixed by government authority. Presumably the exercise of eminent domain by one public service company over the property of the owners of another public service company would be legal, but this again is a question of law concerning which I shall not attempt to express an opinion.

One other amendment to the Transportation Act of 1920, or rather a supplement to that Act, ought to receive careful consideration. The great interstate railway corporations are creatures of individual states. We are looking forward to the time when the entire country will be served possibly by only fifteen or twenty railroad companies, and the question ought to be seriously asked whether these great interstate transportation agencies should be creatures of the states instead of the federal government.

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Compulsory federal incorporation of railroads might raise difficult legal questions, but apparently the obstacles here are not insuperable. Compulsory federal incorporation might delay the voluntary consolidation of railroads, and for that reason it would seem wise to enact a law making it possible, but not compulsory, for railroad companies to change from state to federal corporations. We ought to look forward to the time when the great interstate transportation systems will be subject, not to individual states, but to the federal government as regards their corporate powers and obligations.

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PREHISTORIC TERMINOLOGY.

By EDWIN SWIFT BALCH.

(*Read April 25, 1925.*)

Paleolith and Paleolithic Period, Neolith and Neolithic Period, are terms of prehistory I have long objected to. As far back as 1906, I went on record in disapproval of them. In April, 1923, I read at the Annual General Meeting of the American Philosophical Society a paper entitled, "Prehistoric Misnomers" in which inter alia the misleading character of these terms and of the newly invented term Mesolithic Period were discussed at some length. At that time it did not occur to me that other students of prehistory besides myself might have a grievance. But in the November–December, 1924, number of "Natural History" there are six papers about Early Man and in three of them the authors, Sir Ray Lankaster, Dr. George Grant MacCurdy, and Mr. J. Reid Moir, register complaints about the terminology relating to him.

Sir Ray Lankaster brands the term Quaternary as objectionable and suggests abolishing it but retaining the term Pleistocene. Some geologists, level-headed Boyd Dawkins among them, are also opposed to Quaternary while others are in favor of it. Now Quaternary covers all of the strata following the Pliocene and implies a fourth great geological period different from the Tertiary, while Pleistocene, or its now obsolete equivalent Post-Pliocene, covers some only of the strata following the Pliocene and implies merely a variation from the preceding Pliocene. The Pleistocene is, in fact, a continuation of the Pliocene with, of course, changes due to evolution in the organic and inorganic world. These changes were unusually rapid, owing to the fluctuations in the Polar ice-caps, but assuredly there is no natural barrier between the Pliocene and the Pleistocene. The term Quaternary might be held of value if it were synonymous with the Age of Man and indeed it was so considered at first by some geologists. But this no longer holds. For unquestionably man was in existence in the Pliocene and possibly in the

Miocene. Certainly the facts and the evidence seem to show that it would be wise to adopt Boyd-Dawkins' and Lankaster's view and drop Quaternary from geology!

Dr. MacCurdy complains of the lack of precision in the definition of terms causing confusion and differences of opinions in prehistory. The very title of his paper "What is an Eolith?" is proof that there are still doubts and uncertainty in the subject. MacCurdy considers that the so called Paleolithic Period is characterized by unpolished stone implements found in Pleistocene deposits and the so called Neolithic Period by polished stone implements found in deposits of later date. He therefore considers stratigraphy as the basis on which Stone Age chronology rests. He then continues: "Granted that there be an Eolithic Period, the definition of an eolith becomes a comparatively simple matter. An eolith is a flint (or other stone) that has been shaped or utilized by man or his precursor during the geologic period known as the Tertiary."

Most prehistorians, I believe, take the same view as MacCurdy. They look on *time* as the determining factor in the status of stone implements. They take the terms Eolithic, Paleolithic, Mesolithic and Neolithic Periods literally. These Greek terms sound well, they are more poetical than the English Dawn Stone, Old Stone, Middle Stone and New Stone Periods. And almost certainly their poetical resonance tends to cause their employers to forget their meanings. According to this chronological terminology, eoliths could occur only in the Pliocene and perhaps the Miocene and would stop abruptly at the beginning of the Pleistocene; so called paleoliths would be found only in the earlier three quarters of the Pleistocene, whose last archeologic quarter now masquerades sometimes as the Mesolithic Period; so called neoliths appear with the early Recent and would lose their name and their status with the coming of bronze; bronze implements in turn would vanish when iron comes to the fore. According to this view, a bronze cannon of the time of our Revolution, that is a bronze implement of war, is not a bronze implement. And this last, it seems to me, is a good example of the misleading character of the entire nomenclature.

It is thanks to this chronological terminology that stones and periods have gradually become inverted in the minds of many pre-

historians. It is a fact that stone implements were recognized long before Stone Periods were invented. And it is obvious this must have been the case; stone implements had to be known individually, before they could be thought of collectively. This is certainly true of the so called New Stones or neoliths and of the so-called Old Stones or paleoliths. That is to say, it was only after the two great classes of implements were recognized in separate entities that time labels were affixed to them in masses. This seems forgotten or at least neglected now. For purposes of nomenclature periods are thought of and placed before stones. And putting periods before stones is putting the cart before the horse.

Petrographically, there are no Dawn Stones, Old Stones, Middle Stones, nor New Stones. Petrographically, stone implements belong to vintages antedating by millions of years the advent of man. When talking of stone implements, however, it is not the age of the stone, it is the chipping and the polishing of the implements that is thought of. And it is the presence of the chipping and the polishing, not the time when these were done, that is of primary importance.

In my opinion, stone implements should be labelled descriptively, in accordance with kind and shape, not in accordance with time: that is in accordance with what they are, not in accordance with when they were made. And since the chipping and the polishing are the attributes which strike us first about stone implements, those should receive first consideration. How can this be done? It is very simple! Abolish the inaccurate and misleading terms Old Stone Age, Paleolithic Period and paleolith, Middle Stone Age or Mesolithic Period, and New Stone Age, Neolithic Period and neolith. And substitute for them in English the accurate and descriptive terms Chipped Stone implements and Chipped Stone Period, Polished Stone implements and Polished Stone Period. As Greek terms, however, would doubtless be required for international purposes, Rhectolith (breakable or broken stone) and Xestolith (polished stone) may be suggested. Dr. Walter Woodburn Hyde, Professor of Greek at the University of Pennsylvania, on whom I called for assistance, considered these terms covered the situation probably as accurately as any that could be invented.

As an example of the difference in clarity between the terms

Chipped Stone and Old Stone, and Polished Stone and New Stone, consider the following imaginary case. Suppose some one ignorant of the subject were to bring you an implement from each of the two great classes and ask you to state in plain English what they were, what would your answer be? If you said "These are stone implements: this is a Chipped Stone implement: this is a Polished Stone implement," it would require almost no explanation for your questioner to understand; he would merely have to look. But if you said "These are stone implements: this is an Old Stone implement: this is a New Stone implement," it would necessitate a lengthy explanation to make him understand that Old and New did not refer to the stones petrographically, and that the cutting of the Old Stone implement might date only from yesterday while the polishing of the New Stone implement might date from ten thousand years back.

The less harmful terms Eolith and Eolithic Period, however, might perhaps be allowed to stand. Man certainly must have used at first natural unworked stones and pebbles, and stones and pebbles fractured by himself into unrecognizable shapes; in fact he still uses them and always will. There must have been a period preceding the invention of formed chipped stone implements when man's only stone tools were so primitive that they can not be identified as specimens of his handiwork. This period therefore is and can be only a mental conception to us. Yet it must have existed! And for these unrecognizable artefacts and this visionary yet actual period the names Dawn Stones and Dawn Stone Period are possibly as appropriate as any that could be invented.

The name eolith, however, is at present applied by many prehistorians to the Kentian and Foxhallian implements. But the illustrations accompanying Mr. Moir's paper, as well as those given in Dr. Osborn's paper in the November–December, 1921, number of Natural History, prove conclusively that the Kentian, Foxhallian and Cromerian implements already show form. They are the precursors of all the other formed chipped stone implements which come down through the ages, even to the Tasmanians who were in a pure Chipped Stone Period and whose last survivor died about A.D. 1876. These East Anglian implements were christened eoliths when

their characteristics were still scarcely recognized, but they are similar to and belong to the same class as the implements of the so-called Paleolithic and Mesolithic Periods, the class of recognizable formed Chipped Stone implements.

The point I wish especially to emphasize is that a stone chipped by man or a stone chipped and polished by man into a recognizable implement, is a chipped stone or a polished stone implement, whether the chipping or polishing was done in the Pliocene, the Pleistocene, or this morning. The primary and secondary underlying characteristics of such stones are kind and shape, not time. And widely as the view seems to be held by prominent prehistorians that time is the determining factor in the status of stone implements and correct as this view is under the accepted nomenclature, I must insist that it is this chronological terminology and its literal acceptation that causes most of the confusion and differences of opinion in the science of prehistory. Struggling to advance this science with those old men of the sea terms of neolith and paleolith to trip you up, is like fighting with one hand tied behind your back.

Mr. Reid Moir finds various interpretations of the term "Chellean" and thinks we need to have it "rigorously defined." This objection would apply equally to all the other terms of a similar kind now in use, such as Solutrean and Magdelenean. Undoubtedly, it would be difficult to define these terms more rigorously than they already are, but when such an experienced prehistorian as Mr. Moir feels the necessity for such definition, we may take it for granted that it is necessary. These local names came almost of themselves, because when stone implements were discovered varying in types and shapes from those previously known, the simplest means of specifying them was to affix to them the name of the locality where they were first found. To a prehistorian these names certainly suggest certain types and shapes, but, like the terms paleolith and neolith, they are open to objection on account of the element of time. For instance, does the term Mousterian refer only to implements from strata between the Acheulean and the Aurignacian, or does it apply to all implements of Mousterian types no matter whence they come. Personally I favor the latter view. The important thing, however, is to have a terminology in regard to

the shapes and types of stone implements conveying the same meaning to all prehistorians, and if the exact meaning of this local nomenclature can be agreed on and generally accepted, probably it is the best thing which could be invented for the purpose.

That three such distinguished prehistorians as Lankaster, MacCurdy and Moir complain of the vagaries of prehistoric terminology is pretty good evidence that this is decidedly imperfect. Where there is so much smoke, there is some fire! And this state of things points, it seems to me, to the need of some concerted action to amend it. Such concerted action is already voiced in Sir Ray Lankaster's suggestion to call an international conference to formulate an authoritative list of clearly defined terms in regard to the study of the antiquity of man.

The need as well as the importance of such a conference must be obvious to anyone acquainted with the subject. At present the terminology is in a state of "go as you please" with prehistorians "muddling along somehow." And it does not seem likely that prehistorians, to whom many years' usage have crystallized the meanings they personally attach to certain terms, would be willing to change their views about the meaning of those terms unless there is some authoritative international agreement.

If such an international conference could be brought about, it would insure a most necessary exchange of views, even if it did not codify prehistoric terminology into absolute uniformity. But how can an international conference be made a reality? There's the rub! Frankly I do not see the answer, which I must leave to others. The only suggestion I can make is to have a symposium on the subject at a future Annual General Meeting of the American Philosophical Society. If some of our leading American prehistorians could be gathered together here to discuss the matter from their various standpoints, at least a step forward would be made towards clarifying materially a needlessly involved branch of science.

PHILADELPHIA, PA.

THE APPLICATION OF AUTOMATIC SYNCHRONIZATION OF X-RAY EXPOSURES TO THE STUDY OF INTRA-THORACIC MOVEMENTS.

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AND

CHARLES N. WEYL, B.S.,

(*Read April 24, 1925.*)

X-ray films are records of the relative densities of the objects interposed in their path. The organs in the chest contrast sharply in their penetrability to the x-rays because the heart and great blood vessels are solid, while the lungs are comparable to a fine meshed sponge filled with air. X-rays of normal chests should then show the heart and part of the aorta in the center and, radiating from the root of the lungs, whence the air passages and the arteries and veins are distributed to the lung substance, there should be recorded branching trunks of decreasing caliber. Any disease which changes the contour or proportions of the heart or great vessels, or any disease which changes the relative density of the lung as compared with its supplying branches, or any lesion of the lung which consists of a spot of increased density, is one suitable to recording by the x-rays. On these facts depends the value of the x-rays in the diagnosis and observation of disease in the chest.

The organs of the chest, unique in their contrasting density, are also unique in the complex physiological movement they present. Within each respiratory cycle, that is inspiration and expiration, there occur four heart cycles, each cycle consisting of a diastole, the resting and filling phase, and a systole, the emptying or pumping phase. In most patients respiration can be arrested at any position or phase for the time of an exposure. But the heart's activity is not even momentarily controllable by the will. And the physiological movements of the heart and arteries present a constant problem in securing x-ray films that are accurate and comparable.

The heart changes in size and shape as it contracts, and with each beat it discharges about 75 cubic centimeters of blood into each of two arterial systems, one supplying the lung, the other the rest of the body. The pulmonary arteries, which chiefly concern us, curve and branch to distribute blood to all parts of the lung. These curved elastic tubes, suddenly receiving the heart's output of blood, tend to straighten out just as does a hose when the water pressure is suddenly increased. And, as blood flows out from the arteries, there is a fall in pressure and the arteries gradually resume their curve until the next heart beat. Because of this intermittent discharge of blood, the heart and arteries constantly disturb the lung substance. Moreover, the pulse wave in the chest travels from 3-4 meters per second in the larger tubes, to 6 meters per second in the smaller. Consequently, during an exposure of even 1/60 second, the practical minimum, the pulse wave would travel at least 5 centimeters, so that 1/60 second would be too long if the exposures should fall during the time of the pulse wave. And the changes in size of the heart and in the curves of the arteries do not allow one to get either comparable or truly stereoscopic films, unless the exposures occur at the same phase of the heart cycle. For, if the x-ray film is made to study the size of the heart, it should show it at some chosen moment, either full or empty of blood, in order to be comparable with the normal average or with other films taken at different times in the patient's history. If the x-ray film is made to study the lung, it should show it when as little as possible disturbed by the heart and pulse wave; otherwise, many fine vessels and spots of disease, particularly in the lower two-thirds of the lung substance surrounding the heart, are blurred or even quite unrecognizable. Furthermore, stereoscopic films reveal fine detail, normal and pathological, with much greater accuracy when each film of the pair records the fine markings equally and clearly. Thus each film reinforces and supplements the other, giving true stereoscopic vision, and allows one to differentiate the radiating normal markings, even when overlaid by the rib shadow, from the more irregulary distributed lines and spots of disease. The disturbance due to the heart and the arteries is, of course, greater in the lower two-thirds of the lung. Not only is the heart situated at this level, but the volume

of the elastic and compressible lung substance is greater and the pulsating arteries are longer than in the upper third, where the lung narrows to a conical tip supported by the chest wall. Therefore, films exposed when the lungs are relatively quiet are essential for accurate study of disease in the lower two-thirds of the lung substance. Examples of such disease are bronchiectasis and the tuberculosis of children, in whom the majority of tuberculous lesions occur in the area surrounding the heart.

The next section deals with a mechanism using the heart beat or pulse wave to supply an impulse to close the x-ray switch and give the basis for synchronization of exposures with any desired phase of the heart cycle.

A mechanism was required which would expose an x-ray film at any desired phase of the heart cycle. It was necessary that the device should be

1. Sensitive,
2. Stable,
3. Precise,
4. Easily operated.

Sensitivity required that the device respond to abnormally weak heart beats, not only in adults but in children as well.

Stability required that the apparatus should respond only to the desired heart impulse and never to extraneous stimuli such as involuntary motions of the patient or operator, or noises in the laboratory.

Precision required that the mechanism should expose the x-ray film at *exactly* the desired phase of the heart cycle.

Ease of operation was deemed essential since the device was used as a routine aid in the study of lung and heart diseases, as well as for intrathoracic research.

The lack of any one of the first three requirements would have rendered the apparatus practically useless and the lack of the fourth would have seriously curtailed its usefulness.

A number of methods were considered, tried and rejected before a satisfactory solution was obtained. A brief description of three of these methods may make clear the superiority of the mechanism finally adopted.

The first scheme was essentially acoustical. A microphone placed over the patient's heart delivered its electrical output to a vacuum tube amplifier. In the output of this amplifier was a relay intended to be actuated by the amplified electrical pulses corresponding to the acoustical heart pulses entering the microphone. This relay in turn actuated a time lag device thereby permitting exposure of the x-ray film at any chosen interval after the heart beat. This apparatus, while quite sensitive, was extremely unstable. The slightest frictional motion between the patient and the microphone sent a pulse through the amplifier which energized the exposure relay. Almost imperceptible noises in the laboratory had the same effect.

It was then decided to employ the minute electromotive forces generated in the body synchronously with the heart cycle. But since this method involved the use of the electrocardiograph, the rather elaborate preparation of the patient required when such apparatus is used, was considered a sufficient reason to use a more direct method if possible.

A purely mechanical method was next tried. A tambour sealed with very thin rubber was connected pneumatically by means of a rubber tube to a funnel-shaped applicator. The mouth of this funnel was firmly placed on the neck of the patient over the carotid artery. Thus the rubber diaphragm was displaced in synchronism with the arterial pulse. The tambour carried a tiny aluminum strut cemented to the center of the rubber diaphragm. When this strut was displaced due to the motion of the diaphragm, it mechanically closed the electrical contact of a sensitive relay. The mechanical difficulties of such a scheme will become at once apparent when it is mentioned that with some patients the displacement of the thin rubber diaphragm does not exceed 1–5000 of an inch.

The apparatus finally developed is sensitive and stable; results are readily and exactly reproducible; and the device is easy to apply.

Reference to Fig. 1 will make the principle of operation clear. Details are omitted in this diagram for the sake of clearness. *L* is a powerful light source, (stereopticon type of incandescent lamp). *C* is a pair of condensing lenses. *M* is a very small galvanometer mirror which is fastened to a flat phosphor-bronze galvanometer suspension ribbon, a horizontal section of which is shown at *U*. The torsion of this ribbon keeps the mirror *M* normally in the position shown in the diagram. *F* is an ordinary glass funnel which is con-

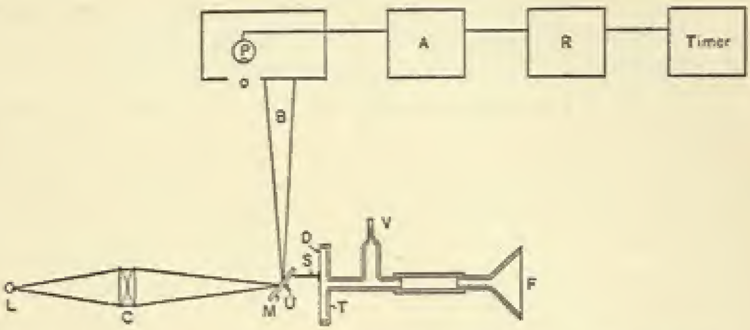

FIG. 1.—Schematic diagram of apparatus for automatic synchronization.

nected to the tambour *T* by means of a flexible rubber tube. The tambour *T* is sealed with a diaphragm *D* of extremely thin rubber. By means of a specially constructed lever system, which, for simplicity is represented by *S* in the diagram, any motion of the diaphragm *D* is imparted, amplified about ten times, to the mirror *M* which is then rotated about *U* against the restraining torsion of *U*. *P* is a photo-electric cell of the vacuum type, which is contained in a compartment having a light-admitting aperture at *O*. This photo-electric cell is connected electrically to the relay *R* through the vacuum tube amplifier *A*. The purpose of the relay *R* will be made clear later.

If the open end of the funnel be placed against the neck of the patient over the carotid artery, an impulse from this artery will travel through the rubber tube and displace the diaphragm *D*. This will in turn rotate the mirror *M* which deflects the beam of light *B* on the photo-electric cell, causing a momentary current of extremely small magnitude, approximately 10^{-8} ampere, to flow through the cell. This current which is amplified by means of the vacuum tube amplifier closes the relay *R*. This relay *R* closes 0.043 second after the pulse at *F*. This interval can be materially shortened by a somewhat more complicated apparatus. If no greater lag between the carotid pulse (or the apex thrust) and the exposure of the roentgen-ray film is desired, the relay *R* can actuate the roentgen-ray transformer primary directly. If, however, a greater time is desired, it is necessary to introduce a lag-timing device. For this purpose a standard roentgen-ray exposure timer was converted into a lag timer. Instead of having the timer determine the duration between beginning and end of exposure, it was adjusted to determine the duration between the closing of the relay *R* and the beginning of exposure. The length of exposure was controlled by a circuit breaker.

Referring again to Fig. 1, *V* is an adjustable capillary vent for equalization of the pressure in the tambour, thereby assuring the return of the diaphragm *D* to the normal position after each pulse. The entire apparatus with the exception of the funnel and attached rubber tube was enclosed in a light-tight cabinet so that no stray light should affect the photo-electric cell. The electrical connections and the mechanical details of adjustment have been omitted for the sake of clarity and brevity.

The mechanism will operate with stability when the motion of the diaphragm is as much as 1–5000 inch.

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LOGIC AND THE RELATION OF LIFE TO MECHANISM.

By Edgar A. Singer, Jr.

(*Read April 23, 1925.*)

Away from Ionian beginnings, from the atomism of Democritus and Descartes, from the cosmogonies of Kant and Laplace, from the ideals of exact science as understood today, has set in a recent current toward a new theory of cosmic history. From an essay just appearing, "The Discontinuities of Evolution," by my distinguished colleague, Professor Lovejoy of Johns Hopkins, I take a word of orientation:

> Unanimity [says Lovejoy] is not, perhaps, an attribute most distinctive of philosophers. Yet on one issue, at least, there has been, not assuredly a universal yet a very extensive and striking convergence of opinion. Thinkers of many opposing schools have concurred in declaring that the sequence of temporal changes constituting the total history of our solar system from nebula to man, is not, properly speaking, continuous, that it does indeed in certain respects show breaks or "chasms," that it exhibits the "emergence" from time to time of absolute novelties, discontinuous variations in no way deducible from or explicable by any characters of the prior members of the series.[1]

Though in a single sentence it would be difficult to sum up a doctrine in which such divergent thinkers as Boutroux, Bergson, S. Alexander, Kemp Smith, Hobhouse, Laird, Baldwin, Sellars, and the veteran Lloyd Morgan could concur without reservation, yet I think Lovejoy's summing cannot be misleading in the emphasis it puts on two words: the *discontinuous*, and the *new*.

Lovejoy, I mean, cannot be mistaken in pointing out that the whole sense and fate of a system introducing into our vision of nature's history "the emergence of absolute novelties, discontinuous variations in no way deducible from any characters of the prior members of the series"—the fate of such a system must hang on its understanding of that peculiar "newness" on which it would have continuity to break. "What is meant by the 'new'? [Lovejoy puts the question.] The word is manifestly equivocal, and there is

[1] University of California Publications in Philosophy, V., 175, 176.

a sense in which the constant appearance of new things is patent and indisputable. If the adjective 'new' is used without specification of some limited sense, the theory of emergent evolution becomes pure banality; it asserts what nobody denies. Obviously any change means novelty in some sense." [1]

What is meant by the new? The practiced exposition of a Lloyd Morgan may be counted on not to have overlooked a point so obviously critical. "The orderly sequence of natural events [he writes in "Emergent Evolution"] appears to present from time to time something genuinely new. Salient examples are afforded in the advent of life, in the advent of mind, in the advent of reflective thought."

"But," so his thought meets our critical question—"but, if there be only regrouping of preëxisting elements, nothing new emerges, there is no emergent evolution." [2]

One of the few advantages we enjoy, who come late into the game of science, is an opportunity to profit by the failures of our fathers. What is life? they asked; and answered, it is a breath. This breath became a ghost haunting them through the ages, and sometimes it was called *soul*, sometimes *entelechy*, but always it remained what at first it had been, something non-mechanical added to "the machine that is to us" making it vitally *go*. But we have come to ask, what if this vague mystery were but the reflected vagueness of the earlier mind's understanding of what it was to look for? Instead of *ghost* we write *new:* Whether anything *new* emerges as thought searching space and time passes from the spread of mechanism atraverse a surface enclosing the apparatus of life? Could any clearer definition be given this groping question than that made explicit in the negative statement of Lloyd Morgan? "If [as we pass from mechanism to life] there be only regrouping of preëxisting elements, nothing *new* emerges."

And yet the very clearness with which this question is formulated has combined with the best tradition to limit our scope. For there is no better tradition to guide the "economy of science" than that which in classic days Democritus if he did not initiate at least so

[1] Loc. cit., 178.

[2] Adapted from loc. cit., 176.

brilliantly followed: To express all we can of the properties distinguishing gross bodies in terms of the internal arrangement of parts differing in fewer ways. What wonder then that the modern biologist faced with Lloyd Morgan's question should think of regrouping only as internal rearrangement? But he can conceive no such inner arrangement as from inanimate elements might compose the activities of life. Hence "emergent evolution" triumphantly emerges, spirit of an ancient ghost.

However, beside *internal regrouping*, there is that I may call *external*.

The logician has long been conversant with the peculiarities of a term he himself invented, the *fundamentum divisionis*. In the broadest possible sense this is but a principle of classification, of which principles more than one is available for arranging the objects of our experience. As it is possible to catalogue one's library so that the very same title appears in a number of references, whereby a single work takes on a number of descriptions, so in the museum of the mind any object whatever may altogether shift its properties as we relate it to the rest of experience first by one then by another *fundamentum divisionis*. Of all the differences distinguishing methods of classification, none is so remarkable for the contrast of properties it evokes as that which lies between grouping in terms of *mechanism* and grouping in terms of *purpose*. One may imagine what difference a library would show if its volumes arranged in like sizes were regrouped under like subjects. Nor would any be astonished if a mechanically little volume proved teleologically big.

But I would not weary with a logician's subtleties all spread in abstract formulas. Let me devote the rest of this paper to an experiment, though it be but an experiment in words and meanings. It ought to demonstrate by the simplest of examples the marvelous change undergone by our description of the very same object as our reflection on it shifts from the mechanical to the teleological standpoint.

The experiment consists in a sort of game I beg you join in: To find the name of an object X from the description offered of it. Reminiscent of nothing more than of some childish riddle, this game

has come in great fashion with modern science since Grassmann's "Ausdehnungslehre" of 1844 showed how delicately it could be played to try out definition.

As though it were a game, then, I ask you to consider what *X* there is in nature such that

(1) Members of the *X*-class have no mechanical definition;
(2) Laws governing the *X*-class have no mechanical explanation;
(3) By these laws the behavior of an individual *X* may be explained, but not predicted;
(4) The present behavior of an *X* is dependent on the future;
(5) The behavior of an *X* is independent of surroundings.

A being susceptible of no mechanical definition; one governed by laws having no mechanical explanation; laws enabling us to explain but not predict individual behavior; behavior which depends on a finitely distant future; and which does not as a whole depend on the mechanical present! Such is the *X* described, in whose description I can think of having omitted no peculiarity adduced by vitalist or emergentist to separate life from mechanism.

And yet the *X* whose description has seemed to dig so deep an abyss between itself and all things mechanical is nothing but the watch ticking in my pocket. Strange, no one has seized on Thomas Huxley's suggestion: the "vitality" of living things and the "horologity" of time-pieces are generically like conceptions. No one, I mean, has bethought him that mechanism may break down on meeting the metal of my watch case, and within some entelechy preside over all that so purposefully goes on there. Why do chronometers present no chasm, no abyss, no emergence of absolute novelties, no discontinuous variations inconsistent with any mechanism?

For my watch or any art-work, atom by atom submissive to universal mechanism, at once it is seized as a whole and set in teleological grouping takes on all the characteristics of the *X*-class described. This thing of springs and cog-wheels then assumes an horologity "new" with all the "newness" vitality has laid claim to. At least, such is my thesis, thesis of a mere logician who would count all this newness whether of life or of watches no disorder in nature

but only new order in its describing; necessary and most valuable outcome of an alternative classification.

But to test the assertion that the description given of my X-class fits not only life but art-work, for X let us write "time-piece" and try out our original statements:

(1) Time-pieces are susceptible of no mechanical definition. How should they be indeed when their meaning connotes only likeness of purpose, the which to our knowledge is accomplished by mechanisms as disparate as sun-dial and stop-watch, as chronoscope and hour-glass? But a mechanical definition of this heterogeneous medley would have to find the mechanism shared by all in common, yet shared by nothing not to be called a time-piece. I say no more, but reflect in passing that a mechanical definition of a life common to amœbas and Aristotles must be equally difficult to formulate, and for precisely similar reasons.

(2) Laws governing time-pieces have no mechanical explanation. In fact it is generally admitted that the only laws controlling objects classed together on the sole strength of their purpose are essentially statistical in nature, subject to individual exception. But it lies in the very meaning of a law of mechanics to suffer no exception; a single planet a trifle late to its appointments would upset the law of gravitation throughout the whole spread of nature. From which too follows our third point, —

(3) The behavior of an individual time-piece may be explained but not predicted by the laws governing chronometers. For the normal may serve to explain; the universal is needed for prediction. The exactest calculation applicable to teleological classes is a most accurate calculus of chances. Yet this purely logical result of teleological classing furnishes with its most baffling traits the *élan vitale* of Bergson, of "Creative Evolution." I can only observe that in its unpredictable explicability, Bergson's *élan vitale* enjoys no real advantage over my *élan horologique*.

No lengthy defense is needed of our fourth condition, —

(4) The persent behavior of time-pieces depends on events of the future. How could it be otherwise of any object classed and named for its purpose only? For the purpose of an event is a result not

certain but well-calculated to follow. And this following must involve the lapse of a finite interval, else our object could be described in differential-equations and would relapse at once into mechanical classification. My watch, for example, would never have served me as a time-piece had I not expected its hands to keep up a constant velocity. Now velocity to be sure is a differential conception; but *constant* velocity is not. And I take occasion to comment that not because life is life is its present explained by its future, but because it shares with clocks, cannon and trombones a teleological *fundamentum divisionis*: they all peer into the integral future, or at least we do for them when we give them the names they bear. And as through this finite future, in a world where everything flows, any purposeful thing must traverse many situations yet be expected to arrive at the one result, let this reflection hint at an explanation (which might profitably be made much fuller) of that strange fifth condition, —

(5) Time-pieces may behave in the same way in mechanically different surroundings. However this teleological property may shock our sense of mechanism, yet we gratefully recognize that time-pieces do enjoy it. Else little good would it do me to carry a watch in my pocket, for if its teleological working were threatened by every vicissitude besetting the quietest day's journey, I might better trust my time-keeping to the less vicissitudinous coursing of our unperturbed sun.

My experiment must be brought to, rather than let come to a conclusion. Elsewhere I have considered some of the many questions suggesting themselves at this moment:[4] What is the specific place and difference of life in the domain of the purposeful, the place neither instrument nor organ, however like life, can intrude on? How may the living body be conceived as moving, like some pulse or vortex, through the continuous medium of mechanism of which and in which it has its being?

But though these matters lie far outside the cadre of our present canvas, enough has been brought within to justify an attitude toward the significant things of our day: toward the "vitalism" of

[4] Mind as Behavior, Ch. IV., "The Pulse of Life."

a Driesch, the "creative evolution" of a Bergson, the "emergencies" of Lloyd Morgan.

In life's appearance is there anything so "genuinely new" as to be no possible regrouping of preëxisting elements? We answer, there is nothing; but the kind of regrouping necessary and sufficient to make the properties of life emerge in our reflection is not the kind of regrouping the litature of the subject discusses. It is not *internal* but *external* novelty of arrangement. From the mechanical to the teleological *divisionis fundamentum* there is indeed a leap, but it is a leap from attitude to attitude of the contemplative mind: it is no leap in nature's exact and reliable order.

To the ideals of exact science; to the cosmogonies of Kant and Laplace; to the mechanics of Descartes, Democritus; to the spirit of Greek beginnings our thought goes back untroubled. Life however rich in purpose lives in and by means of that unbroken world-old mechanism whose

> unbegreiflich hohe Werke
> Sind herrlich wie am ersten Tag.

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ABSORPTION AND EXUDATION PRESSURES OF SAP IN PLANTS.

By Dr. D. T. MacDOUGAL.

(*Read April 24, 1925.*)

Previous studies have identified the reversible variations in diameter of tree-trunks with changes in cohesion tension of the water column in the recently formed wood, and similar variations also take place in herbaceous stems. Daily changes of diameter of succulent plant bodies such as those of the cacti have been seen to follow a different program and to be due to variations in the water deficit in the succulent cortex which may be many centimeters in thickness.

The present paper presents some studies on nature of negative, absorption pressures and of bleeding, exudation pressures in plants based upon studies in hydration, water deficit, permeability and colloidal reactions of cell-masses in such succulent plants. Both absorption and exudation phenomena are demonstrated to be due to localized causes. Cell-masses abutting on bore-holes in stems have been induced to show absorption or exudation pressures at the will of the experimenter. The possibility of the participation of root-action or "root-pressures" is not disproven, but on the other hand no positive evidence for such participation has been brought to light in these experiments. Intake of water by empty vessels or tracheids is registered as "negative" pressures on manometers attached to stumps of stems, or in any manner which connects the instrument with spaces containing gases at less than atmospheric pressure. The capillary intake of water implied is not to be confused with the satisfaction of living cell-masses by osmotic absorption or hydration of cell colloids. Both absorption and exudation pressures as measured by a manometer attached to bore-holes filled with water in stems are traumatic phenomena. Their measure-

ment however yields results of great value in determining osmotic values, water-deficit and permeability of the tissues.[1]

The Hydrostatic System.

The essential features of the hydrostatic system of the higher plants include the following: (*a*) The endodermal mechanism of the roots by which water taken in through the root-hairs and root-tips is drawn through the firm and turgid endodermis into the central cylinder by the osmotic activity of solutions in the parenchyma and maturing woody elements. The cells of the endodermis are fully turgid and may have a higher osmotic value than the external cells or internal solutions, but the osmotic value of the sap of the internal cells must be greater than that of the cortex, root-hairs and soil solution in order to carry on absorption. (*b*) A continuous cohesive column of water extends in the form of a meshwork through the tracheæ and tracheids of the stem to living cells of the leaves. The osmotic action of the sap in the central cylinders of the roots may cause a positive upward pressure to varying heights in this conducting system. (*c*) The evaporation of water from the menisci of the walls of cells in the leaves sets up a tension by which an upward movement, "the ascent of sap," is caused. The longitudinal tension thus set up is accompanied by contraction of the conducting vessels which is a marked feature of the daily reversible variations in tree-trunks, and which has also been found in small herbaceous plants. (*d*) The participation of living cells in this process is limited to the construction of mechanical elements, development of solutions, and maintenance of colloidal material. Dead root-systems have long been known to carry on absorption from the soil; the passage of water upwards is through elements from which the protoplastic bodies have disappeared, and I have recently demonstrated that a pine tree may be killed by partial defoliation in such manner that cohesion tension may be maintained in what is perhaps a diminished water meshwork or column, and that daily reversible variations in diameter of the trunks may continue for days or even weeks after all

[1] MacDougal, D. T., "Permeability and the Increase of Volume of Contents of Living and of Artificial Cells," *Proc. Amer. Phil. Soc.*, 62, 1–25, 1924. "Reversible Variations in Volume, Pressure, and Movements of Sap in Trees," Publ. 365. Carnegie Inst. of Wash., 1925.

cells in the stem, and in the remaining leaves may have become dead and brown. The colloidal remnants of these elements are mechanically undisturbed and continue to evaporate water from the surfaces which is replaced by imbibition from the column in such manner as to maintain tension and slight upward movement.[2]

The only external manifestations by which the action of the hydrostatic system of the plant may be estimated are: (*a*) amount of intake of water; (*b*) amount of transpiration from the shoot; (*c*) amount of water forced out of hydathodes by endodermal action, and (*d*) registration of the daily reversible variations in stems consequent upon altered cohesion tensions in the ascending meshwork or column of water.

Experiments in Releasing or Inducing Absorbing and Exudation Pressures.

A method by which gauges or manometers are connected to holes bored in stems or to the cut surfaces of stumps of stems has been used extensively in the two centuries since it was first devised by Stephen Hales.[3] The results are discussed under the headings of "root-pressure," "sap pressure," "bleeding pressure" or exudation pressure in the literature. This technique may in some instances force sap under "root-pressure," or as it is proposed to term it "endodermal pressure," directly into the gauge where it may be recorded, but in all other cases the various pressures are caused by or released by the disturbances of cells or tissues in setting up the experiments. The present paper is the outcome of an effort to localize the forces operative in producing "negative pressures," or absorption pressures as they will be termed, and of exudation pressures, which are normally exemplified only in nectarial secretions or excretions.

Exudation and Absorption.

When a hole is made in a woody stem and the leading tube of a manometer is sealed into connection with the cavity, or when a stem is cut off and the manometer tube is fastened over the stump

[2] MacDougal, D. T., "Reversible Variations in Pressure, Volume, and Movements of Sap in Trees," Publ. 365. Carnegie Inst. of Wash., 1925.

[3] Hales, S., "Vegetable Staticks," London, 1727.

the system of liquid in the instrument is initially at atmospheric pressure. If now an addition is made to the volume of the liquid in the cavity which is continuous with that of the instrument a positive pressure (exudation pressure), or one greater than atmospheric will be set up. If on the other hand water is taken from the system including the cavity in the tissues of the plant the pressure will be less than atmospheric and the level of mercury in the open end of a U tube, the other end of which is connected with the system of water in contact with the living tissues, will fall indicating that some of the water has been absorbed and a suction exerted there which is usually measured as "negative pressure," but which will hereafter be more fitly and adequately designated as absorption pressure.

Exudation pressures measured by a manometer fitted to a bore-hole in the flank of a stem or to the end of a stump might be due to osmotic action of the endodermal mechanism of the root, or to the action of cells exposed on the surfaces of cavities or stumps. Actual demonstration of the head or height to which this so-called "root-pressure" may force water up in a stem is singularly lacking. It is true that droplets of water exuding from the tips of grass blades and from the tips of certain plants are commonly and perhaps rightly attributed to the action of the endodermal mechanism in forcing water upward through the conducting systems. On the other hand it is known that in small herbaceous plants the tension set up in stems by the transpiratory action of living cells in the leaf is such that the conduits are in a contracted condition due to the excessive pull which has its ultimate origin in the menisci of the transpiring cells in the leaf. This contracted condition is of course incompatible with any conception of a "root-pressure" head of water forced up from below in the same conduits. From the comprehensive critique of observations on exudation made by Molisch in 1902 it is fairly evident that in a large number of plants in which high pressures were exhibited or in which renewed disturbance of a wounded surface caused an accelerated flow that osmosis due to disintegrating material or to the collapse of turgid cells may be taken to be the cause of the exudation. On the other hand when this phenomenon results in long continued flow at low pressure such as exhibited by the vine some participation of the endodermal mechanism is suggested.

Pressures as high as 9 atmospheres in *Aesculus Hippocastaneum* were described by Boehm in 1892. These pressures were measured by closed manometers maintained for long periods in attachment to a cavity in the trunk. Figdor obtained pressures of 6–8 atmospheres in tropical trees in 1898, and Molisch over 6 atmospheres in native Austrian trees in 1892.[4]

The results of my recent observations of pressures in the trunks of the Monterey pine afford well-defined evidence of the manner in which such pressures originate in coniferous stems. Previous records of the Coniferæ include no maxima of exudation pressures greater than 114 mm. Hg = about 0.15 atm. Bore-holes driven tangentially to the wood of the second year previously fitted with closed manometers which would realize the maximum pressure with a minimum amount of exudate showed maxima as great as 4 atm. in about 40 hours after the beginning of the experiment. The ascending water column in these trees occupies the wood of two or three previous years and the bore-holes penetrated this wood in such manner as to disturb the maximum number of living cells in contact with water-filled conduits. The bore-holes had a depth of about 40 mm., a diameter of about 10 mm., and would therefore have a surface of 1256 sq. mm. A tangential surface shows about 52 medullary rays to the sq. mm., so that the boring cut across 30–50,000 medullary rays, each exposing an average of 5 cells. In addition to the osmotic action of the contents of ruptured cells and to the collapse of the abutting cells which would force water into the manometric cavity a large number of resin canals were cut, and as there are one or two in each fibrovascular bundle, and as these are 70 to 140 mm. long, a great amount of material under pressure would be poured from them into the cavity and would immediately set up pressure in the system in addition to the imbibitional and osmotic action of this material in drawing water from the wood cells.[5]

Contrary to the practice of many experimenters, the preparations were completed within 5–10 minutes from the time the bark was cut

[4] Boehm, J., "Ueber einen eigenthümlichen Stammdruck," *Ber. d. deut. Bot. Ges.*, 10, 539, 1892. Molisch, H., "Ueber localen Blütungsdruck und seine Ursachen," *Bot. Ztg.*, 60, 45–63, 1902.

[5] MacDougal, D. T., "Reversible Variations in Volume, Pressure, and Movements of Sap in Trees," Publ. 350, Carnegie Inst. of Wash., 1925, Esp. Fig. 8.

through in making the bore-hole. Consequently it was revealed that during the first few minutes or for as long as half an hour absorption from the manometer tube occurred causing "negative" pressures which soon gave way to exudation. The instrument became clogged with resin within four or five days and no further pressures of absorption or exudation were shown. It is not probable that the maintenance of the preparation for several months would have been followed by pressures as were found by Boehm and Molisch in *Aesculus Juglans, Ulmus, Tilia,* etc. The cells contiguous to the bore-hole in *Pinus* become filled with resinous material and hardened so that osmotic action would be inhibited.

The "negative" or absorption pressures noted above may have been due to the direct absorption of water by the living cells exposed or to the intake of water by wood cells in which a tension existed. The preparation was arranged in such manner that withdrawal of water from the manometer bore would be minimized. If the manometer is fastened to the cut stump of this pine stem or if the bore-hole is made so deep as to pass through the water-filled wood, then only negative or very slight positive or exudation pressures will be realized (0.15 atm. as noted above). Thus I have recently found that manometers attached to bore-holes in trunks piercing only the water-filled layers show exudation pressures of 2 to 4 atm., while similar instruments fastened to cut stumps of branches within a few centimeters registered only negative or absorption pressures. In the last-named instance the manometer connects not only with the ends of the empty wood cells which are air-conducting but also with the spiral ducts of the protoxylem which number 4–500 in this pine and which afford a free passage for air or liquids and thus make it impossible to register more than a slight exudation pressure which might be set up by the action of living cells on the cut end of the stump. In one instance the air column in the closed end of a manometer attached to the stump of a Monterey pine was compressed from a length of 110 mm. to 104 mm., an increase of about 0.06 atm.

It was notable that manometers fastened to bore-holes in large roots some distance from the base of the trunk at first showed absorption pressures for a few minutes then exudation pressures

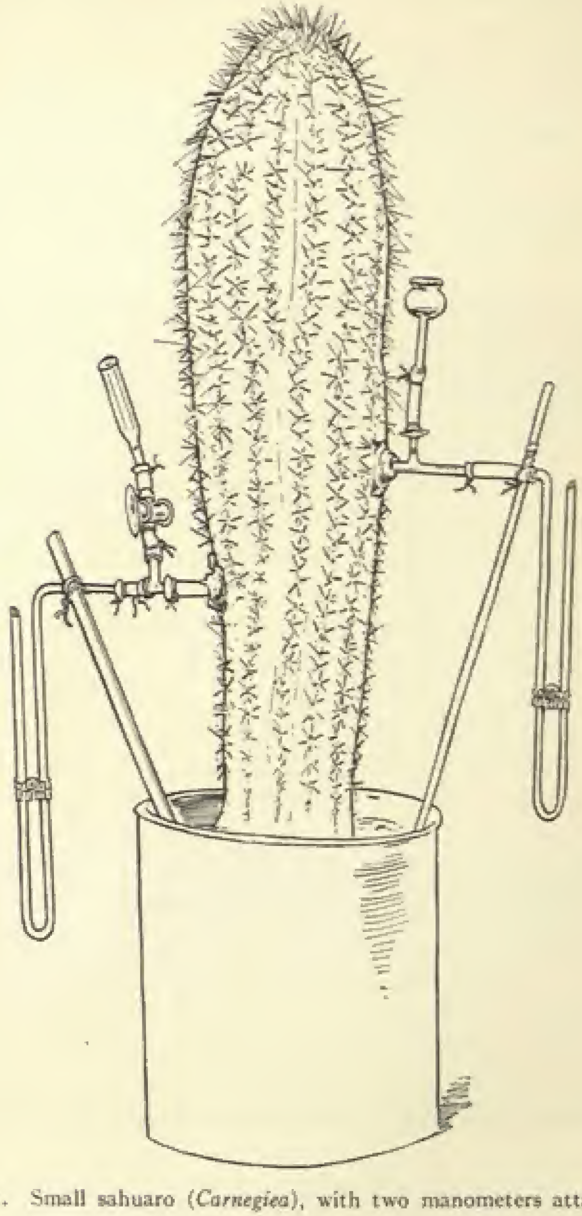

FIG. 1. Small sahuaro (*Carnegiea*), with two manometers attached as in Fig. 2.

which reached a maximum over 2 atm. The daily reversible variations in diameter in large roots are the reverse of those in the trunk, enlargement taking place during the daylight period. No essential difference could be found between the course of exudation pressures in large roots and in trunks. The pressure in both cases is due to localized osmotic action of living cells which act independently of the varying tension of the complex water column in the wood of the trunk and root.

The experimental work described in the present paper was arranged to test the absorptive and exudation action of tracts of living cells in which root-action would be eliminated and in which the conducting tracts were filled with water. The giant tree cactus or sahuaro (*Carnegiea gigantea*) of Arizona presents such conditions. The massive cylindrical stems of these plants reach a height of 13 meters, with a diameter from 25 to 50 cm. in mature individuals. A firm central medulla 10 cm. in diameter is enclosed in a shell of anastomosed woody rods. External to the wood is a cortical layer 5 to 12 cm. thick, the outer part of which is chlorophyllose. Small bundles run from the central cylinder to the clusters of spines on the apices of the longitudinal ridges, representing vestigial branches, and fascicles corresponding to the leaf traces ramify thickly through the heavy layer or cortical layer. The daily reversible variations in thickness of such trunks is one of varying water deficit of the living cells of the cortical layer in contradistinction to that of woody tree trunks in which the cohesion tension of the water column in woody cells is the determining factor (Fig. 1).

The fibrovascular tracts appear to be filled with liquid at all times and solutions move upward in the conduits at a very low rate. No detailed examinations of the conduits have been made except to test their behavior with respect to a few colloidal dye solutions. Of these the particles of Congo red are so large as to effect but little entrance into the bases of trimmed root-systems. Orange G is conducted upward in the most recently formed wood and in the smaller bundles and traces at a rate of about 4 mm. per hour in plants with a water deficit by which the cortex increased 53 per cent. in thickness when placed in water. Methyl blue moved at a similar rate but did not leave the main bundles. The staining effects of

acid fuchsin were equally indeterminate and appeared to be confined to the wood of the single individual which was tested. The dye had moved upward a distance of about 60 cm. in 6 days, which was at a rate of 3–4 mm. hourly.

The sap of the sahuaro has an osmotic value varying from about 4–7 atmospheres according to the water deficit.[6]

Titratable acidity of the sap at this season varies from 0.81 to 1. ml. KOH 0.1N in the morning to 0.47 to 0.58 ml. late in the afternoon.[7] The sap is so buffered, however, that the dissociated acid does not vary widely from Ph 4 at any time. It is suggested that such a condition may be due to the presence of salts of calcium or sodium with weak organic acids.

When thin sections of the cell-masses with a thickness of a few millimeters are hydrated the effects of the solution on all of the cells is soon realized. The amount of water and consequent increase of size of any cell, or in this case of the thin sections which will be taken up may be expressed by the formula of Ursprung and Blum,

$$Wn = \frac{Vn - Vg}{Vs - Vg} \cdot \quad Ws$$

in which W = wall pressure, V = volume of cell, O = osmotic value of contents, Si the absorptive power of the contents, n the normal condition limiting plasmolysis, and s the saturation point.[8] Briefly, the osmotic absorptive action of the cells continues to a point where it is met by the stretched tension of the walls. Imbibition and the colloidal action of dissolved substances or charged particles in the hydrating solutions will also participate in the action.

When a cavity is made in the great mass of thin-walled succulent tissue of the sahuaro and this cavity is connected with the leading tube of a manometer filled with water, absorption will cause a "negative pressure." These conditions will also draw gases from the intercellular spaces of the cortex which must be released from

[6] MacDougal, D. T., and W. A. Cannon, "The Conditions of Parasitism in Plants," Publ. Carn. Inst. of Wash., No. 129, 1910.

[7] Richards, H. M., "Acidity and Gas Interchange in Cacti." Publ. 209, Carnegie Inst. of Wash., 1915.

[8] Ursprung, A., and G. Blum, "Eine Methode zur Messung des Wand und Turgor druckes der Zelle, nebst Anwendungen," *Jahrb. f. wiss. Bot.*, 63, 1–110, 1924.

the instrument. The leading tube of the manometer used in the present experiments was provided with an upright branch in which was fitted a stopcock and which terminated in a filling funnel (Fig. 2).

The readings fail to show the osmotic potential of the absorbing cells by the increase in volume of the cells which abut on the cavity made in the tissues. In the earlier part of any experiment the

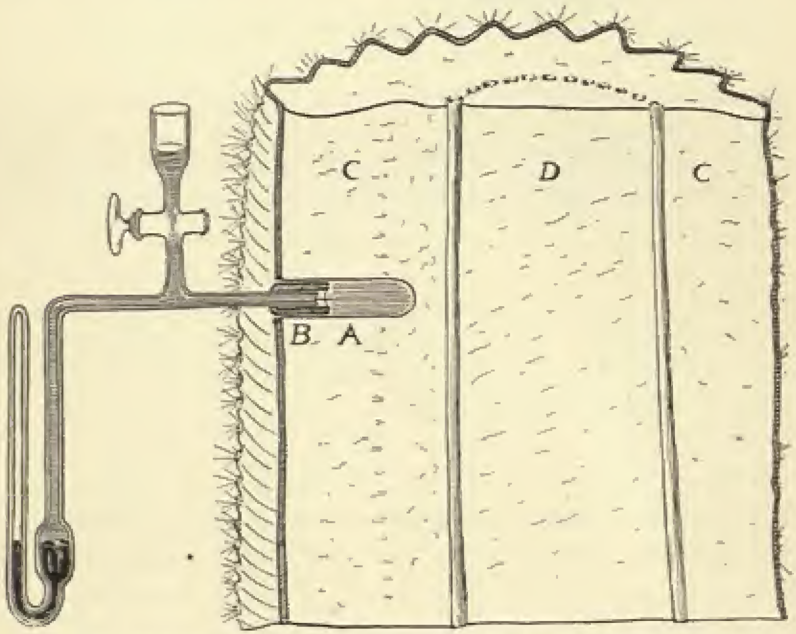

FIG. 2. Section showing attachment of manometer to cavity in cortical tissues. *A*, Cavity containing solution continuous with that in the horizontal arm of manometer which has closed free arm. *C*, *C*, Cortex. *D*, Medulla.

masses of cells surrounding the cavities expanded with increased turgidity, part of this expansion resulting in diminution of intercellular spaces and greater rigidity, but some of the increase is in the axes radial to the cavity. Expansion in this direction would of course tend to compress the liquid in the cavity and thereby take up some of the space freed by absorption. When the observations are carried through a number of days the cells contiguous to the cavities become approximately satisfied, after which this last modification remains in a static condition, except as to the thrust of swelling cell-masses behind them.

A further series of modifications which might be introduced by the action of the oxidases which appear in the wounded tissues of the cavity, and of the increased osmotic action following hydrolyses can not be evaluated in any practical manner. All of these modifying factors are, however, to be taken into account in absorption pressures in addition to others which may appear as a concomitant of special anatomical structures.

Finally, it is obvious that absorption of water from the cavity in the cortex by the cells which abut upon it would result in increased turgidity and lessened osmotic value of the sap of these cells, which would consequently lose water to their neighbors in a series leading away from the cavity. A gradient thus established would include long chains of cells which would be only remotely affected by material in other cavities a few centimeters distant.

It is to be noted that in the experiments described in the following pages that the manometer was of a design by which it might be opened readily, air released and the filling liquid replaced. Several possibilities were opened by such an apparatus, including the effect of different solutions separately or in combination. The first preparation was made with a detached branch and placed on a laboratory table where it received direct sunlight for 4–5 hours daily. The conditions presented were identical in all essentials with those of a branch in place on the trunk. Readings were made as below:

Pressures are given as height of column of mercury sustained, in mm.

Date.		Absorption Pressure.	Temp. of Tissue.	Remarks.
Feb. 11 ..	11:15 a.m.	0	....	Filled with distilled water.
	2:10 p.m.	−20	18 °C.	
	4:10 "	−20	18.5	
	7:00 "	−10	....	
12 ..	9:00 a.m.	−10	18	Reset.
	11:00 "	−16	....	"
	2:00 p.m.	−24	19	"
	4:00 "	−36	19.5	"
13 ..	10:25 a.m.	−30	....	Released and set to 0.
	11:05 "	−12	....	" " " " "
	11:30 "	−16	....	" " " " "
	2:50 p.m.	−20	....	" " " " "
	4:40 "	−30	....	" " " " "
	7:00 "	−24	....	" " " " "

Date.		Absorption Pressure.	Temp. of Tissue.	Remarks.
14 ..	9:30 a.m.	−12	16.5	Reset to 0 and filled with $CaCl_2$ 0.01*M*.
	10:50 "	−30	17	
	11:30 "	−30	17	
15 ..	12 noon	0	....	Reset and resealed.
	1:30 p.m.	−30	16.5	Reset and intake of 0.3 c. needed to replace.
16 ..	9:30 a.m.	+ 2	15	
	2:20 p.m.	−62	17	Reset and 0.5 cc. used.
	5:30 "	−24	....	"
17 ..	9:30 a.m.	− 8	....	Reset and gas released.
	12 noon	−20	....	Reset.
	2:45 p.m.	−56	....	"
	7:30 "	−36	....	"
18 ..	9:30 a.m.	−24	17	Reset.
	11:00 "	−20	17	
	2:00 p.m.	−36	18	
	3:45 "	−34	18	
	4:30 "	−34	18.5	Reset.
19 ..	9:15 a.m.	−28	17.5	Reset.
	10:30 "	−16	....	
	11:00 "	−22	18	
	11:30 "	−24	....	
	1:30 p.m.	−40	....	
	2:00 "	−48	....	
	4:30 "	−64	....	
	6:30 "	−34	....	Reset, using 0.2 cc.
20 ..	9:00 a.m.	−46	19	
	10:15 "	−42	19	Reset, using 0.2 cc.
	11:00 "	−16	19	
	11:40 "	−12	....	
	1:30 p.m.	−18	....	
	5:00 "	−32	20	
	7:00 "	−34	....	
21 ..	9:00 a.m.	−30	18.5	Reset, using 0.2 cc.
	10:30 "	+ 2	....	
	11:00 "	− 4	....	
	1:30 p.m.	− 4	19	
	3:00 "	....	....	Reset, the cavity having been enlarged and the fitting changed, using rubber tube sheath to glass.
	3:30 p.m.	−20	....	
	4:00 "	−28	....	
	7:00 "	−28	....	
22 ..	7:00 a.m.	−48	16	Reset.
	6:45 p.m.	−34	....	"
23 ..	9:00 a.m.	−40	14.5	Measurements discontinued.

The dissection of the plant showed a cavity 6 cm. in depth terminating at the woody ring. The bared cells were blackened by the action of the peroxides which are so abundant in the tissue. The tissues within a radius of a few centimeters of the cavity appeared to be saturated and turgid from extreme hydration.

The test includes a preliminary period in which the cells abutting on the bore-hole absorbed water only and were hydrated to the maximum yielding water in turn to contiguous cells leading away longitudinally and radially. Such absorption continued at a rate measurable by this instrument for periods of 4 to 6 hours and raised pressures equivalent to a column of Hg 36 mm. in height. Replacement of water by a solution of $CaCl_2$ 0.01 *M* was followed by the registration of pressures of 48–64 mm. Hg. These maximum pressures would be attained by the absorption of 0.2–0.5 ml. of liquid. The differential action in water and in calcium solution is clearly correlated with the degree of permeability in the two cases. Slices hydrated under the auxograph in water showed a distention of 53 per cent. in water on the second day and then began to contract. Distention in a calcium solution reached 50 per cent. in the same time and continued for some time afterward. The volume of the cells in both cases being the resultant of the factors included in Ursprung's formula. The introduction of calcium into the cavity lessens the permeability of the walls and plasmatic layers to organic substances and hence reduces losses of osmotically active material from the cells. The calcium solution at the beginning has an osmotic value of about 0.4 atm., while the contents of the cells approximate 7 atm. Absorptive action may therefore continue for a long period and effect a distention of the cells greater than that in water.

In another series parallel to the above a manometer was fitted to a plant 60 cm. in height with a closely trimmed root-system set in a dish of air-dry sand. The manometer system was at first filled with water. Absorption pressures of 6 to 18 mm. Hg were registered at temperatures of 16–18° C. Replacement of the water by a 0.01 *M* solution of $CaCl_2$ at 10 a.m. on Feb. 13 was followed by an initial reaction by which an absorption pressure of 26 mm. Hg was seen at 3:30 p.m. During the continuance of the test pressures increased in

some cases as long as 25 hours, culminating on Feb. 21 at 88 mm. Hg, and 90 on Feb. 23, this maximum being reached in 24 hours after resetting. Temperatures ranged from 15–20° C. The higher pressures in this preparation may be in part attributed to better fittings.

The next test was arranged to determine the action in a cavity which was first filled with water which was later replaced with a sugar solution about isotonic with the cell-sap. This was done with a plant 40 cm. in height with a trimmed root-system standing upright in a dish of dry sand. The manometer as set up had the free arm sealed. Pressures were registered as below. The preparation then stood for several days when the end of the free arm was cut so that pressures were read directly in millimeters of mercury as follows:

Date.		Pressure.	Temp. of Tissue.	Remarks.
Feb. 21	7:00 p.m.	− 7	....	Filled with water. This represented lengthening of column of Hg 100 mm. long originally.
22	7:00 a.m.	− 7	....	
	7:00 p.m.	− 6	....	Reset.
23	9:00 a.m.	− 4	....	Reset.
24	9:00 "	− 4	....	Manometer arm cut.
28	10:00 "	....	....	Water replaced with sucrose 0.3*M* = 7 atm.
	11:00 "	− 3	....	
	1:00 p.m.	−12	....	
	7:00 "	− 9	....	Reset.
March 1	8:00 a.m.	− 5	....	Reset.
	7:00 p.m.	+27	....	Reset; some gas released.
2	9:00 a.m.	+23	....	Reset.
	11:00 "	+ 4	....	
	2:00 p.m.	+10	19 ° C.	
	5:00 "	+32	....	
	7:00 "	+40	....	
3	9:00 a.m.	+54	19.5	
	10:30 "	+54	18.5	Reset.
	4:00 p.m.	+17	23	
	7:00 "	+35	22	Reset.
4	9:00 a.m.	+30	17	Reset.
	12 noon	+ 2	18	Reset.
	7:00 p.m.	+50	23	Reset.

Date.		Pressure.	Temp. of Tissue.	Remarks.
5	7:00 a.m.	+43	19	
	7:00 p.m.	+57	22	Reset.
March 6	7:00 a.m.	....	21	Stopcock open.
	11:00 "	+ 4	21	
	3:00 p.m.	+13	23	
	4:00 "	+18	23	
	7:00 "	+24	25.5	
7	7:00 a.m.	+32	21	Reset.
	10:30 "	+ 6	22	
	2:00 p.m.	+48	23	
	10:30 "	+42	....	
8	7:00 a.m.	+45	20	Reset.
	7:00 p.m.	+18	....	
				The preparation was now allowed to stand for 10 days without release of pressure which steadily increased.
18	9:00 a.m.	+47	18° C.	
19	7:00 "	+45	20	
	3:00 p.m.	+48	23	
20	7:00 a.m.	+48	22	
	3:00 p.m.	+56	24	
23	9:00 a.m.	+52	23	
	4:00 p.m.	+60	....	
24	9:00 a.m.	+59	22	
25	9:00 a.m.	+62	22	
	7:00 p.m.	+63	25	
27	7:00 p.m.	+66	25	

The expected absorption from water was displayed. Replacement by sugar solution approximately isotonic with the cell-sap was followed by a reversal 24–30 hours later when exudation pressures were set up. This increased during the month in which the record was kept, reaching a height of 63 mm. Hg on March 25th. When reference is made to the behavior of living cells under the auxograph it is found that an increase of 25 per cent. in water is followed by a contraction of 5 per cent. in a 0.3*M* solution of sugar.

The action noted would be fairly similar to that consequent to the use of a weak solution of methyl blue in the manometer followed

by a sugar solution. This test begun on Feb. 24th showed absorption pressures of 8 to 26 mm. Hg during the week following at temperatures of the plant of 15 to 22° C. On March 3d, at 4 p.m. the dye solution was replaced with one of sucrose 0.3*M*. Thirty hours later an exudation pressure of 10 mm. Hg was found and such exudation action continued with repeated accumulations of pressures to 82 mm. Hg during the following week at temperatures of 15 to 23° C.

In all of these cases the absorption of water from the system results in lessened concentration of the cell sap and the subsequent action of the sugar would be to cause plasmolysis with a loss of some of the cell contents accompanying or consequent upon increased permeability. The next set was arranged to begin with water, to be replaced by calcium solution with consequent lessening of permeability which would then be replaced with a solution of sucrose. The test was made with a globoid branch about 12 cm. in diameter, set in a dish of dry sand. The measurements were as follows:

Date.		Pressure.	Temp. of Tissue.	Remarks.
Feb. 20..	10:45 a.m.	....	....	Set up with water.
	10:55 "	−20	....	
	11:10 "	−38	19.5° C.	
	1:30 p.m.	−46	20	
	3:00 "	−52	25	Reset.
	4:00 "	−36	22.5	
21..	7:00 a.m.	....	....	Reset; air released.
	7:00 p.m.	−50	....	Reset.
23..	9:00 a.m.	−46	....	Reset.
	10:20 "	−14	....	
	3:30 p.m.	−34	17	
	7:00 "	−42	21	
24..	9:00 a.m.	−10	18	
	2:30 p.m.	−38	18	Reset, and filled with $CaCl_2$ 0.01*M* = 0.4 atm.
	4:00 "	−42	19.5	
	7:00 "	−46	....	Reset.
25..	10:00 a.m.	−48	....	"
	2:30 p.m.	−48	19	
	8:00 "	−48	....	

Date.		Pressure.	Temp. of Tissue.	Remarks.
26..	9:30 a.m.	−48	16.5	Reset.
	12:15 noon	−28	18	
	1:30 p.m.	−40	....	
	7:00 "	−44	....	Reset.
27..	9:30 a.m.	−52	....	Reset.
	1:30 p.m.	−34	....	"
28..	9:30 a.m.	....	....	Calcium solution replaced with sucrose 0.3*M* = 7 atm.
	11:00 "	0	16	
	1:00 p.m.	0	16.3	
	7:00 "	0	17.5	
Mar. 1..	8:00 a.m.	− 3	15	Reset.
	8:00 p.m.	0	....	System open.
2..	5:00 p.m.	0	....	Reset with fresh sugar solution.
	7:00 "	+ 6	....	
3..	9:00 a.m.	− 6	17	
	10:30 "	+ 4	17	
	2:00 p.m.	+ 6	18	
	4:00 "	+ 8	20	Reset.
4..	9:00 a.m.	−18	17	Reset, with fresh solution.
	12 noon	+ 2	18	
	2:00 p.m.	....	19	Reset.
	7:00 p.m.	+ 4	23	
5..	7:00 a.m.	+10	19	
	7:00 p.m.	+40	22	Reset.
6..	7:00 a.m.	....	21	Stopcock open.
	11:00 "	....	21	
	3:00 p.m.	+ 8	....	
	7:00 p.m.	+10	25.5	
7..	7:00 a.m.	+ 6	21	
	10:00 "	+ 8	22	Experiment closed.

Negative pressures during the period when the cells were swelling in water were quickly built up and with a maxima not so high as has been observed in other individuals. This rapid absorptive action during the first three days when the cavity was filled with water would result in an increased turgidity with a diminished osmotic value of the cell contents so that replacement of water by calcium solution in the cavity did not result in higher absorption pressures as were seen in other tests in which satisfaction had not been so nearly attained. The action of the calcium on the wall and plasmatic layers would

however tend to prevent loss of material from the cell and make for long continued absorption.

Replacement of calcium immersing sections under the auxograph with a 0.3M solution of sucrose results in a contraction amounting to 20 per cent. In the manometric experiments above this replacement was followed by a period of very slight activity of any kind. On the fourth day following some exudation was shown. A brief period of absorptive action resulting in a pressure of 6 mm. Hg on the 3d and another in a pressure of 18 mm. Hg on the following day then gave way to continued positive exudation pressures.

The next logical step was to make a test in which the cells were treated to $CaCl_2$ during the first stage of the experiment which would lessen permeability, then with sucrose. Readings of such a test were as follows:

Date.		Pressure.	Temp. of Tissue.	Remarks.
Feb. 27..	10:30 a.m.	....	....	Set up with $CaCl_2$ 0.01M = 0.4 atm.
	11:00 "	−38	....	
	1:30 p.m.	−64	21 °C.	
	3:00 "	−56	21.5	Reset.
	4:00 "	−80	22	
	5:00 "	−86	22.5	
	7:00 "	−86	22.3	Reset.
28..	9:00 a.m.	−74	18	Reset; the system being filled with sucrose 0.3M = 7 atm.
	11:00 "	− 6	19	
	1:00 p.m.	−10	21	
	3:00 "	−24	22	
	5:00 "	−42	22.5	
	7:00 "	−34	22	Reset.
Mar. 1..	8:00 a.m.	−10	18	Reset.
	10:00 "	− 4	18	
	7:30 p.m.	0	22	
2..	9:00 a.m.	+10	18	Reset.
	11:00 "	+14	19	
	2:00 p.m.	+36	....	
	5:00 "	+36	24	Reset.
	7:00 "	+16	....	
Mar. 3..	9:00 a.m.	+44	19	Reset.
	11:00 "	+28	20	
	2:00 p.m.	+44	23	Reset.
	4:00 "	+28	24	
	5:00 "	+36	23.5	
	7:00 "	+62	23	

Date.		Pressure.	Temp. of Tissue.	Remarks.
4..	9:00 a.m.	+92	19	Reset.
	12 noon	+52	23	
	1:30 p.m.	+66	25	
	7:00 "	+66	25	
5..	7:00 a.m.	+20	21	
	7:00 p.m.	+32	25.5	Reset.
6..	7:00 a.m.	+16	23	
	11:00 "	+26	25	
	3:00 p.m.	+54	28	Reset.
	4:00 "	+16	28	
	7:00 "	+36	27	
7..	7:00 a.m.	+86	23	Reset.
	10:30 "	+64	23	
	2:00 p.m.	+60	25	Reset.
	10:30 "	+80	23	Reset.
8..	7:00 a.m.	+40	21	
	7:00 p.m.	+40	20	Reset.
9..	9:30 a.m.	+14	15	Experiment closed.

The use of the calcium solution at the beginning took the cells with their full water deficit and lessened permeability, in consequence of which high absorption pressures were quickly reached—within 7 hours. Replacement of the calcium solution by a sugar solution with an osmotic value of 7 atm. balanced the cell-contents reducing absorptive action to O within 25–30 hours, exudation pressures being shown within another 12 hours. The walls and plasmatic layers having been acted upon by calcium exudation pressures were built up rapidly after each resetting, maxima of 86 and 92 mm. Hg being manifested during the succeeding 7 days the experiment was continued.

In the foregoing experiments positive exudation pressures were exhibited by preparations only in which sucrose at a concentration isotonic with the cell-sap was used. It was now desirable to determine the effect of other substances and concentrations. First, a solution of sucrose at 0.2*M* was tried. Such a solution has an osmotic value equivalent to about 5 atm. Living sections which showed an increase of 43 per cent. in distilled water increased but 16 per cent. in such a sugar solution. The action of such a solution in a cavity to which a manometer had been fitted is illustrated by

the following data obtained from a plant 70 cm. in height with closely trimmed root-system set upright in a dish of sand (Fig. 1).

Date.		Pressure in mm. Hg.	Temp. of Tissue.	Remarks.
March 13	4:00 p.m.	....	....	Set up with sucrose 0.2*M*.
	4:30 "	−20	....	Reset: air released.
	7:00 "	− 5	18 °C.	
14	10:00 a.m.	−20	15	Reset: air released.
	1:30 p.m.	−14	17	
	5:00 "	−14	18	Reset.
	7:00 "	−12	18	
15	7:00 a.m.	−25	16	"
	9:00 "	−12	16.5	
	5:00 p.m.	−25	19.5	Reset: air released.
16	10:00 a.m.	−18	17	Reset.
	2:00 p.m.	− 8	20	
	7:00 "	− 6	20	"
17	7:00 a.m.	−10	19	"
	11:00 "	0	19.5	
	7:00 p.m.	0	22	
18	8:30 a.m.	+ 4	19	
	2:00 p.m.	+12	22	
	5:00 "	+16	23	
	9:00 "	+16	22	
19	7:00 a.m.	+ 32	20	
	3:00 p.m.	+ 40	23	
20	7:00 a.m.	+ 72	21	
	10:00 "	+ 82	21.5	
	3:00 p.m.	+ 96	25	
	5:00 "	+100	25	
	7:00 "	+106	24	
21	7:00 a.m.	+ 66	22	
23	9:00 a.m.	+224	23	
	4:00 p.m.	+226	26	
24	9:00 a.m.	+226	22	
	3:00 p.m.	+228	25	
25	9:00 a.m.	+228	22	
	7:00 p.m.	+234	24	
26	9:00 a.m.	+236	22	
27	7:00 a.m.	+238	24	
	7:00 p.m.	+240	25	

The pressures stood near this maximum for two days at the end of which time the stopcock of the manometer was opened allowing some of the liquid to escape and the column of Hg to come to O. In the presence of the sucrose at 0.2*M* the cells of a thin section of the

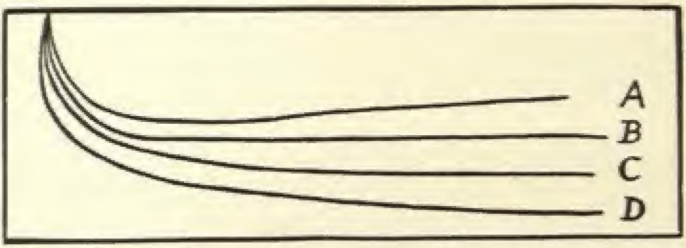

FIG. 3. Tracings of auxographic record of distention of slices of cortical tissue of *Carnegiea* in various solutions. *A*, Water; *B*, HCl = Ph 3; *C*, NaOH = Ph 11, and *D*, $CaCl_2$ 0.01M.

cortical tissue in which the bore-hole was made would come to full distention in about 20 hours, the maximum being reached in water in 12–14 hours. In the test with the manometer an indefinite mass of cells would be concerned, the sucrose passing some distance from the cavity so that absorbing action continued for about 2 days, or about twice the length of time of distention of a thin section. Diminution

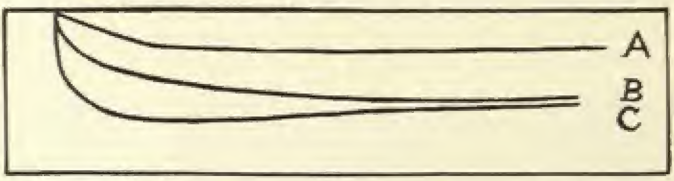

FIG. 4. Tracings of auxographic record of distention of slices of cortex of *Carnegiea* in various solutions. *A*, Sucrose 0.2M; *B*, phenylalanin 0.1M; *C*, Water.

of the pressure supposedly coincident with the escape of material from the cells begins at about the same time in thin sections as in the manometer cavity (See Fig. 3, 4). The exudation pressure thus begun was followed for 8 days, and reached a maximum of 240 mm. Hg before the instrument was reset at 0.

A second manometer was fitted to the opposite flank of the plant upon which the last experiment was performed, the two being so

widely separated as to have no possibility of influence on each other. The second instrument was filled with a 0.1*M* solution of phenylalanin. It has been found repeatedly that living cell-masses show an osmotic distention in such solution greater than that in water. The record was as follows:

Date.		Pressure in mm. Hg.	Temp. of Tissue.	Remarks.
March 14	11:00 a.m.	....	....	Set up with phenylalanin 0.1*M*.
	1:30 p.m.	−10	17 °C.	
	5:00 "	−20	18	Reset.
	7:00 "	−10	18	
15	7:00 a.m.	− 5	16	Reset: air released.
	9:00 "	− 4	16.5	
	5:00 p.m.	− 6	19.5	Reset.
16	10:00 a.m.	− 5	17	Reset: air released.
	2:00 p.m.	−10	20	
	7:00 "	−10	20	Reset.
17	7:00 a.m.	−10	19	"
	11:00 "	−10	19.5	"
	7:00 p.m.	−12	22	"
18	8:30 a.m.	−12	19	"
	2:00 p.m.	−10	22	
	5:00 "	−12	23	Reset: air released.
	9:00 "	−10	22	
19	7:00 a.m.	−14	20	Reset.
	3:00 p.m.	−16	23	
20	7:00 a.m.	−16	22	"
	10:00 "	−14	21.5	
	3:00 p.m.	−18	25	"
	5:00 "	− 2	25	
21	7:00 a.m.	....	22	Stopcock open.
23	9:00 a.m.	....	23	Stopcock closed.
	4:00 p.m.	+ 2	26	
24	9:00 a.m.	+12	22	
	3:00 p.m.	+18	25	
25	9:00 a.m.	+24	22	
	7:00 p.m.	+26	25	
26	9:00 a.m.	+12	22	Reset: air released.
	7:00 p.m.	+12	24	" " "

No further change taking place in the next few days the observations were closed. The disturbances in this case followed a course something different from that in the presence of the sugar solution, but a reversal from absorption to exudation pressure was seen. Sections from another plant measured under the auxograph a few days earlier showed a distention of 43 per cent. in water, 16 per cent. in sucrose at 0.2*M* and 37 per cent. in phenylalanin 0.1*M*. Thin sections did not attain equilibrium until about the end of 30 hours, or double the length of time necessary for full distention in the sugar solution. Similarly, absorption pressures continued for twice the length of time in phenylalanin as in the sucrose solution (See Fig. 4). Satisfaction is followed by some escape of the cell-contents by plasmolysis which is expressed as exudation pressure in the manometric experiment.

The effect of the H–OH concentration on distention and permeability of living cells of the type composing the cortex of cacti has been repeatedly described in previous publications. Distention of cells either living or dried and dead is more rapid in acid solutions at Ph 3–3.5 than in water or alkaline solutions, and reaches a total less than in alkaline solution and sometimes less than in water. Contraction and loss of cell-contents begins soonest in acid with the general effect of setting up exudation pressures earlier in acid than in alkaline solutions. Distention of living or dead cells proceeds more slowly at Ph 10–12 in hydroxides than in water, the imbibitional action of such a solution being greater than an acid one. A longer time is necessary to reach maximum distention in alkaline than in acid solutions. These differential effects are partly masked when solutions are introduced into a cavity in a large mass of cortical tissue for reasons described in another paragraph.

To determine the course of this absorptive-distentive and exudative-contractive action in an entire plant a small sahuaro about a meter in height with trimmed root-system set upright in a container filled with sand and pebbles and placed on a laboratory table. Two manometers were attached to its flanks on opposite sides about mid-height (Fig. 1). The connecting tubes of one were filled with citric acid at Ph 3.5 and the other with NaOH at Ph 10. Readings were made as follows:

Date.		Pressures in Mm. Hg.		Temp. of Tissue.
		Citric Acid.	NaOH.	
March 17	3:45 p.m.	Beginning	....	25° C.
	4:00 "	−12	Beginning	
	4:15 "	−16	− 6	....
		(Reset)	(Reset)	
	7:00 "	−36	− 8	25
		(Reset)	(Reset)	
18	9:00 a.m.	−20	−14	18
		(Reset)	(Reset)	
	2:00 p.m.	−28	−10	21
	4:00 "	−40	−10	22
	5:00 "	−50	− 6	....
			(Reset)	
	9:00 "	−56	− 6	22
19	7:00 a.m.	−52	− 6	20
		(Reset)	(Reset: air released)	
	3:00 p.m.	− 6	− 2	....
20	7:00 a.m.	−12	− 2	....
		(Reset)	(Reset)	
	10:00 "	+ 4	− 4	21
	3:00 p.m.	+ 6	− 4	....
	5:00 "	+ 8	− 4	....
		(Reset)	(Reset)	
21	7:00 a.m.	−20	....	23
		(Reset)	(Reset)	
23	9:00 a.m.	−18	− 8	23
	4:00 p.m.	−14	−10	25
24	9:00 a.m.	−18	−14	22
25	9:00 a.m.	−18	−14	22

No indication of a change in the absorptive action appearing the test was closed at the end of 7 days. The results harmonize with the behavior of thin sections under the auxograph. Rapid absorption, full distention and then beginning contraction of the cells in the acid solution resulted in a change to positive pressure on the third day of the experiment. The resumption of absorption action may be taken to the action of the cells extending away into the cortex by which resumption of absorptive pressure took place. The action of the cells exposed to the action of the hydroxide resulted in a minimum absorptive pressure on the third day, at which time the hydration swelling of the plasmatic layers of cells near the cavity

would be at a maximum and the permeability of the layers greatly increased. The escape of cell-contents did not proceed so far as to set up a positive or exudation pressure however. The action of cell-masses away from the cavity as in the acid solution caused a resumption of absorption pressure.

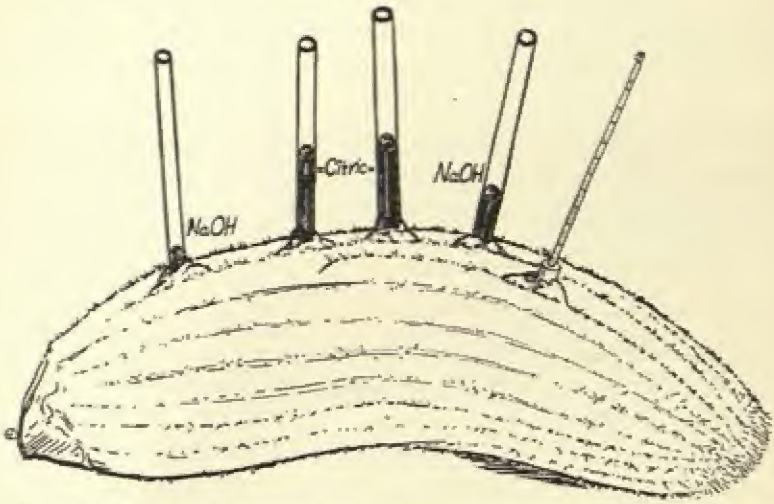

FIG. 5. Branch of *Carnegiea* with burettes containing acid and as indicated attached to cavities in the cortex. The height of the liquid remaining in the burettes indicates relative absorption at Ph 3.5 and Ph 11.

Experiments similar to the above arranged to measure the amount of water which might be taken into bore-holes somewhat larger, yielded some valuable correlations. A branch laid on a laboratory table was fitted with four burettes, and two filled with citric acid at Ph 3.5 and two with sodium hydroxide at Ph 10. The liquids stood at a height of about 20 cm. in the burettes so that absorption began under this pressure and came down to less than half this amount during the course of the observations (Fig. 5). The course of absorption and exudation is illustrated by Fig. 6. At the end of 60 hours the absorption from the acid solution in one pair was 6.4 ml. and 9.1 ml. from the hydroxide; 8 ml. from the acid and 10.5 ml. from the hydroxide in the other. After a few hours in which action was indeterminate, exudation began and at the end of four days 0.9 ml. had been added to the acid solution in one burette

and 0.4 ml. to the other. Coincidentally 0.3 ml. had been added to the solution in one burette containing hydroxide and 0.4 ml. to the other. A day later exudation reached a total of 0.5 ml. in each of the two hydroxide solutions, but remained stationery in the acid. The expression of these amounts of liquid against the weight of a mercury column would probably have resulted in very small pressures. Absorption and distention by cell-masses as measured by the auxograph, and by the manometer will doubtless be found to be coincident with an osmotic balance in which the cell layers hold a normal position. Exudation may be inferred to be accompanied by losses and displacements resultant from a disturbance of osmotic balance and in some stages attended by plasmolysis.

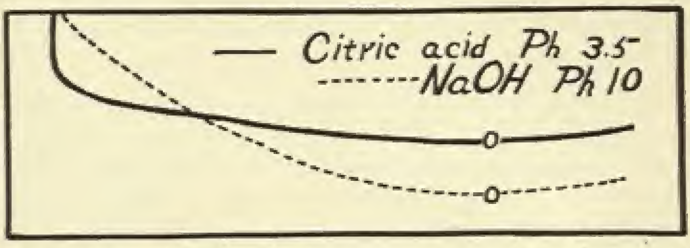

FIG. 6. Graphs showing rate of absorption of water from solutions at Ph 3.5 and 11 as in Fig. 5. Absorption came to an end at o in the curves, after which exudation is shown.

A manometer fitted to a bore-hole filled with juice expressed from a separate branch of the sahuaro showed absorption pressures for two days, when the experiment was discontinued. The sap is mucilaginous, and soon blackens so that good measurements were not possible.

It is noteworthy that the behavior of another plant, *Opuntia*, in which a mass of parenchymatous cells served by a meshwork of vascular tracts shows reactions similar to those of *Carnegiea*. A manometer fitted to a cavity made in the flat joint of a platyopuntia with a cell-sap having an osmotic value of 10 to 12 atmospheres at Ph 4 showed absorption pressures of 4 to 66 mm. Hg during the first 4 days, at temperatures of 15.5 to 23° C.

Replacement of the water with a solution of sucrose about $0.3M$ = about 7 atm. was followed by negative or absorption pres-

sures of 33 mm. Hg at first, which lessened and on the third day showed a positive pressure of + 10 mm. Hg.

A second *Opuntia* gave absorption pressures by a manometer filled with water of 10 to 16 mm. Hg for 4 days. Replacement of the water with a sugar solution 0.6*M* was followed by diminished absorption pressures of 4 to 14 mm. Hg for ten days, after which time exudation pressures began which ranged from 6 to 28 mm. Hg at temperatures of 14 to 21° C. Such positive or exudation pressure was followed for more than a month, the intensity gradually increasing to 46 and 50 mm. Hg.

A third Opuntia showed absorption pressure with water for two days. Replacement of the water with sucrose 0.2*M* in citric acid Ph 4 was followed by low absorption pressures for a week, which gradually changed to exudation pressures which had risen to 30 mm. Hg a month from the beginning of the experiment.

Conclusions.

1. Experiments have been carried out to determine the nature and cause of "negative"-absorption and "bleeding"-exudation pressures in plants. Stems of massive succulents with heavy layers of cortex, a large medulla, and with a conducting system filled with water at low tension have been used for recording the course of distention of cell-masses by the auxograph, for measurements of pressures which may be set up by absorption and exudation and for the identification of the changes in permeability which attend such phenomena.

2. A further consideration of exudation pressures in trunks of the Monterey pine emphasizes the fact that maxima much higher than any previously recorded are obtained by a technique which attaches manometers to bore-holes in the two or three most recently formed layers of wood-cells. "Negative" pressures result when manometers are attached to stumps in such manner as to connect with vessels in the protoxylem or with empty wood-cells containing gases at pressures less than atmospheric.

3. Absorption pressure is generally exhibited when a manometer is connected to a bore-hole in a trunk or large root, and may give way in a few minutes to a positive exudation pressure reaching a maximum within 48 hours.

4. Exudation pressures were shown by large roots of the Monterey pine which can not be connected directly with the activity of the endodermal mechanism.

5. Living cells contiguous to a bore-hole in the cortex of the tree cactus (*Carnegiea*) with a water deficit of 25–40 per cent., and a cell-sap with an osmotic value of about 7 atm., set up absorption pressures of 36–52 mm. Hg when the cavity was filled with water.

6. Solutions of $CaCl_2$ 0.01M (0.01) with an osmotic value of 0.4–0.8 atm. in cortical cavities caused absorption pressures of 48–86 mm. Hg. These increased values are to be attributed to the action of the Ca on the colloidal material of the cells by which their permeability is lessened and the escape of vacuolar contents prevented.

7. Thin sections of cortex undergo a period of absorption and distention when placed in solutions of sucrose 0.2–0.3M = 3–5 atm. followed by a contraction or collapse as described in previous papers. Cavities filled with these solutions showed absorption pressure for a day or two after which the escape of cell-contents resulted in exudation pressures.

8. Replacements in cortical cavities showed that water followed by sucrose 0.3M gave exudation pressures of 66 mm. Hg. Water, followed by $CaCl_2$ replaced by sucrose 0.3M gave exudation pressures of 40 mm. Hg. $CaCl_2$ 0.01M replaced by sucrose 0.3M resulted in exudation pressures of 86–92 mm. Hg.

9. The highest exudation pressures resulted when cortical cavities were filled with sucrose 0.2M. Absorption pressures of 20–25 mm. Hg decreased to O on the fourth day, after which exudation pressure slowly rose to 240 mm. Hg. The sucrose solution had an initial osmotic value of about 5 atm.; that of the cell-sap was about 7 atm.

10. Phenylalanin 0.1M induced absorptive pressure for 7 days amounting to 6–20 mm. Hg, which gave way to exudation pressure on the 8th day, reaching a maximum of 26 mm. Hg on the 10th day.

11. The course of development and final results of absorption and exudation pressures are harmonious with known facts as to the influence of H—OH concentration. Cavities filled with citric acid Ph 3.5 developed absorption pressures of 56 mm. Hg on the second

day, followed by a diminution to O and changing to an exudation pressure of 8 mm. Hg on the 5th day, which a day later gave way to absorption pressures. Cavities filled with NaOH Ph 10 developed absorption pressures which came down to 2 mm. Hg at the time a similar preparation with acid was showing exudation pressure. Further action consisted in an increase of this absorption pressure parallel to the action of the preparation with acid.

12. Cortical cavities of larger capacity fitted with burettes containing about 10 ml. of the above solutions showed more decisive action than smaller ones connected with mercury-filled manometers. Absorption continued for about 60 hours; the relative absorption of water from acid solution was as 7 to 10 from hydroxide. A period of indeterminate action was followed by one of exudation which was on a mean of two experiments slightly greater at Ph 3.5 than at Ph 10.

13. Absorption or "negative" pressures in stems are due to osmotic and imbibitional action of living cells upon solutions placed in bore-holes and connected with manometers. The osmotic and imbibitional action of living cells of the leaves or transpiring organs may reduce pressures in wood-cells and vessels so that water may be taken in through the cut surface of a stump or bore-hole and cause a registration of "negative" pressure in an attached manometer.

14. Exudation or "bleeding" pressures in the Monterey pine and in cacti are generally due to the local activity of living cells in cortex, rays, resin ducts, etc., near cavities made in stems or on exposed surfaces of stumps. Such activity is attended by loss of material consequent upon increased permeability of the living cells and presumably by plasmolysis and damage of many cells.

15. Exudation pressures in the tree cactus occurred in the absence of roots or the possible participation of "root-pressures." No definite information as to the participation of roots in exudation pressures in stems was obtained.

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THE GRASS RUSTS OF SOUTH AMERICA; BASED ON THE HOLWAY COLLECTIONS.[1]

By J. C. ARTHUR.

(Read April 24, 1925.)

For fifty years the writer was intimately associated with the late Professor E. W. D. Holway in botanical activities. For the first five years, between 1875 and 1880, we directed our attention chiefly to the identification and distribution of the flowering plants of Iowa, of which state we were then both residents. After that period the fungi began to receive attention, especially the smaller forms and particularly the parasitic ones. As we became more familiar with the botanical field, our activities were gradually narrowed and intensified until in 1895 we began the publication of "Descriptions of American Uredineae," and from that time onward the rusts were our chief concern.

Professor Holway was a man of diversified tastes and superior ability. Whatever he undertook he did unusually well. Beginning his career as a banker, in which occupation he laid the foundation of the competence which enabled him in after years to defray the expenses of collection and publication of botanical data, he became noted as an ardent mountain climber and a successful botanical explorer. His contributions to the critical identification and delineation of the rusts also were by no means insignificant.

When sufficiently released from duties as a bank official, he began his botanical explorations, first in the Selkirks and Canadian Rockies, where also his most important mountain ascents were made, then in Mexico and Central America, and finally in South America.

In recent years he found an enthusiastic and intrepid companion for his travels in Mrs. Mary M. Holway, his wife, who has shared the discomforts and the joys of his explorations, and to whom much

[1] Contribution from the Botanical Department of the Purdue University Agricultural Experiment Station.

credit is due for extent and value of the results. Since the death of Professor Holway on March 31, 1923, Mrs. Holway has supervised the completion of his important publication, the "North American Uredineae," and the assembling and the transfer of his library and specimens to the University of Minnesota.

Having successively brought out of Mexico, Guatemala and Costa Rica by far the greatest number of rusts known for these countries, in each instance much exceeding the efforts of all previous collectors combined, he and his wife decided to give some time to South American exploration. One group of rusts was to receive especial attention, those of the grasses. Such rusts not only include those of the greatest economic importance, but are, with one or two remarkable exceptions, heteroecious, *i.e.*, use very unlike hosts for their life cycle, and therefore invite keenness of observation, and a dependable judgment when dealing with circumstantial evidence, rarely demanded of the collector.

Itinerary in Western South America.

Somewhat over a year (September 4, 1919 to October 6, 1920) was devoted to the Andean region, including the countries of Chile, Bolivia, Peru and Ecuador, and about the same length of time (August 8, 1921 to August 31, 1922) to the eastern region, including the countries of Brazil, Uruguay, and Argentina, revolutionary turmoil preventing entry into Paraguay. It was the original intention to report the explorations of the western and eastern regions separately. A title was announced for the Andean portion, but completion of the article was interrupted by illness of the writer, and the unavoidable delay gave opportunity to combine the study of the two regions.

Professor and Mrs. Holway disembarked at Valparaiso, Chile, September 4, 1919, the season being early spring, and for nearly six weeks explored the region centering about Santiago. This is not only the oldest part of Chile in point of agricultural occupation, but much the best known part in connection with rusts. As might be expected few virgin or protected areas for vegetation were found. From San Felipe Professor Holway wrote to the author: "Every inch pastured, and mists hang low all day. *Puccinia Malvacearum*

flourishes as never before seen, but nothing else found today." Chile was the original home of *P. Malvacearum*, the mallow rust, from which it has spread to all parts of the world during the last fifty years. A letter from San José de Maipo says: "We are still in semi-desert regions; cacti cover the hills. This fine valley is pastured closely." Again from Talca he wrote: "Since leaving Papudo we have been looking for a place where something grew. Sheep, goats, cattle, etc., eat everything to a half inch. Pichilemu was very barren, but we got one new grass rust."

On October 13 they turned southward and went as far as the region about Puerto Varas, a little north of the great island of Chiloe, and west to east from the seashore up into the mountains above the hot springs of Chillan and the copper mines above Rancagua. From the Termas Minerales de Chillan he wrote on New Year's Day, 1920: "Here we are in the mountains at 2000 meters elevation. Yesterday fourteen collections were made, [list of them given]. You will note that I am chasing grass rusts religiously. I intend that it shall be the greatest collection of grass rusts ever made" [in South America]. Again at the same place four days later he says: "Glorious sunsets, especially when the volcano erupts at the right time. Grass rusts of Chile are mostly with covered sori, often on dead leaves and hard to find, being very small." They returned to Santiago the latter part of January, and on February 13 sailed away from Chile, having secured 313 collections of rusts, of which 121 were on grasses.

Bolivia was next visited, entry being by way of Antofagasta, and the first stop for collecting being at Oruro. They soon proceeded to Cochabamba, situated at 8,300 feet altitude on a plateau almost over the divide. Three weeks were spent here with gratifying success. On March 2, 1920, he wrote: "*Puccinia* on *Bouteloua* with a splendid *Aecidium* on *Opuntia*. They are both rather common [on one hillside, as he explains in his next letter], no other grass rust to be found in the vicinity, and the *Puccinia* well developed near the infected cacti." The aecia of this species had been collected in the same region nearly thirty years before, but the associated telia had not before been seen. A week later he wrote: "Bolivia is very charming. New grass rusts every day. I have

found an *Aecidium* on *Stevia* [afterward determined as the similar but less known *Ophryosporus*] and the grass rust going with it—proof perfect—everywhere that I found the Aecidium there was the *Puccinia* [*P. Poarum*]." Still two days later he reports discovering "a very grand Aecidium on a malvaceous host—clusters of four or five cups, very large. Looking for the grass rust belonging to it, I found great quantities of a remarkable *Puccinia*, with brown sori up to one inch long, and with yellow spores, looking more like a malvaceous rust than a grass rust. It's a grand thing, and absolutely no question about the connection!" Could he have foreseen the unique character and unsuspected relationships which the after-study of this rust (*Puccinia interveniens*) revealed, he would have been even more wildly enthusiastic over its discovery. From taxonomic and evolutionary points of view it is probably the most interesting grass rust known at the present time.

From Cochabamba they proceeded to the capitol city, La Paz, and after three weeks went on to Sorato, a hundred miles or so beyond the railroad terminus. Here were scenes to delight a lover of the mountains. On April 19 he wrote: "This is a glorious place, 2,500 population, they say, seems smaller, 7,800 feet elevation, a few hundred feet above the bottom of the narrow canyon. At the head of the canyon, close by, is the glacier-covered Illampu, said here to be 25,000 feet high [in fact 21,290 feet]. All around the mountains rise to 15,000 feet or more. One of the passes is 18,000 feet. It's all straight up and down. I have been going down, and the climb back at night was tough. So today I climbed, and it's much easier to walk *down* after a day's work. I don't call the collecting first class, still I have added a dozen species of grass rusts not before seen."

A post-card from La Paz, dated May 17, where they had returned a week previous, says: "Off at eight tomorrow, going to Yungas." This proved to be their most important excursion into the wilds, and the only one fully over the divide and down the eastern slopes of the Andes. It was a thirty-one day trip on mule back into a region destitute of accommodations for travellers. From San Felipe, at 10,000 feet altitude, which was reached the first night, came a letter saying: "We sat on the edge of a gasoline hand-car, and in seventy

minutes rode the sixteen miles to the summit of the pass, 15,000 feet." Here they were met by a muleteer with riding mules and a pack mule. He continues: "Yungas means a deep valley, and this is a wonder. At the summit was a great cirque, down which we wound, and then it was down, everlastingly down. We had been told terrible tales of the posadas [lodging houses], but we have a room with two windows, or rather holes, cloth covered, and two beds with clean bedding. The posada is a one-story stone building with grass roof," and all kinds of domestic animals outside the door day and night. "The meals are filling," he says, "even though the sheep was trotting around at 11 A.M., and we ate it at 12 M.!!" Some days later he wrote: "For a week past they fed the pig out of our soup kettle, and as they only rinsed it in dirty water, we were glad that the soup was always boiling hot!!" After the first week they were pleasantly entertained at haciendas, the homes of wealthy land owners. Professor Holway's optimistic spirit, which always refused to see the seamy side of things, was not entirely proof against uncleanly food and high altitude, and some time was taken from collecting by indisposition, which at Coroico, the capitol of the province, amounted to more than a week, but Mrs. Holway came through the experience unaffected. La Paz was again reached on June 18, and a stay of nine days completed the collecting in Bolivia, giving a total of 416 numbers, of which 108 were grass rusts.

On June 27 they took train for Cuzco, Peru, heart of the ancient Inca civilization, situated at 11,000 feet above sea level. The stay in Peru, which included a two-days mule trip to Urubamba, winter home of the Incas, ten days in the desert at Arequipa, a few days at Lima, a day or two at Choisica in the foot hills above Lima, and at Santa Clara, altogether about a month, gave 60 numbers, with 14 of them grass rusts. The small size of the collection is fully accounted for by remembering that it was the dry winter season, and that the region for many centuries was the abode of highly civilized agricultural races, even before the coming of the Spaniards.

Ecuador was next visited, a little more than two months intervening between arrival at Guayaquil on July 30 and departure for New York on October 6. The stops for collecting embraced Huigra, Riobamba at foot of Mt. Chimborazo, and Quito, the Capitol, where

they were accorded much social attention. It was at Quito that the Swedish botanist, G. von Lagerheim, gathered many rusts in 1891, while connected with the University there, and who is still interested in the fungous flora of the region, having two botanists collecting for him at the time of Professor Holway's visit. There was also a long trip by mule-back to Cuenca, where there was good collecting, and even a longer one to the gold mines at Portovelo near Zaruma. From the latter place he writes on September 24: "The mule ride here was glorious—44 hours in the saddle—four days without taking our clothes off, sleeping on the ground and in rock piles. Views were stupendous; trails beyond description, the wet forest very beautiful. Third night we slept high up with views over seven ranges." Thus thirteen months of exploration in the Andes closed with unbounded enthusiasm, an enthusiasm for his science even exceeding that for the beauties of nature, although the latter has been here more abundantly illustrated by citations, because by many persons more readily appreciated. There were secured 216 numbers of rusts in Ecuador, of which 23 were grass rusts. Altogether the South American trip yielded 1,002 rust numbers, 266 of them being rusts on grasses, and 10 being the alternate stages of grass rusts, but on other kinds of plants.

Interval of Study.

The interval between the two South American trips was devoted to painstaking and intensive study of the accumulated material. Letters from Minneapolis to the writer averaged two and three a week, and were filled with critical notes and data regarding the species then in hand. On April 14, 1921, he wrote: "It is a pleasure to study this big collection, though I must say that the field work among the mountains is equally a joy." Again not long afterward he says: "This warm weather gives me the fever to see palms and sea and snow-covered mountains, and the desire to tramp some hundreds of miles for more rusts!" The early announcement of plans for a second trip southward, therefore, did not come as a surprise. Although anxious to see the results of the first exploration in print, yet the trying climate of Minneapolis and the urge to secure still more ample material for study caused him to begin preparations for departure before the summer was half over.

On July 23, 1921, Professor and Mrs. Holway stepped aboard the SS. "American Legion" at New York, and after a pleasant voyage a letter was dispatched from Rio de Janeiro on August 8, saying: "Arrived here this morning. It is the most glorious place I ever saw."

Itinerary in Eastern South America.

About 1,045 collections of rusts, 182 being grass rusts, were made during the year and three weeks between arrival and departure from the eastern shores, and all but 34 of these, 19 being grass rusts, were made in Brazil. The itinerary differed somewhat from that of former years in that there were no rough and arduous trips of more than a day's length, most of the collecting being done by short railway or trolley excursions into the regions near large cities.

The city of Rio de Janeiro was made the center of operations from the time of arrival to January 17, 1922, almost daily excursions being taken to places more or less remote, including Nictheroy and its vicinity across the bay, no less than 18 separate names of localities being attached to the collections. During this period of 23 weeks some five or six weeks were spent in the mountain cities of Petropolis, Therezopolis, Friburgo and Nova Friburgo, yielding 137 collections of rusts, of which 18 were on grasses. Another diversion was a thousand mile journey into the state of Minas Garaes, visiting the new capitol of Bello Horizonte, the old capitol of Ouro Prato, the hotel there being over 200 years old but the rooms and food excellent, and also Sabara and Barbacena. A total of 81 collections was made, of which five were grass rusts, and one other was an alternate form on *Solanum*. This trip occupied nearly four weeks, from late in November to the middle of December. Professor Holway wrote under date of December 3, 1921, that Bello Horizonte "is a charming city with a most beautiful country around it. It is early spring, and too early for rusts although there is a wonderful flora now in flower. However, fires have run over all the country, and in my experience that eliminates most of the rusts."

The next collecting center was that of São Paulo, chosen for one reason because "there is a perfect network of railways from here, and many run often so that I can go out in the morning and back at

night," as he wrote on January 20, 1922. São Paulo, a city of about 150,000 inhabitants, lies between 200 and 300 miles southwest of Rio de Janeiro. It was reached by a twelve-hour railway trip.

A month after arrival Professor Holway wrote: "It is still early for rusts, everything very young and fresh. The climate is splendid, and I am feeling wonderfully well. I have covered pretty well all the Santos-Jundiahy Railway, 140 kilometers, walking between stations." A few days later he wrote: "I had a fine day yesterday, getting to the top of the highest peak near here, 1,100 meters only, but with almost all the state of São Paulo visible" from its summit.

The first of the longer trips was northward to the coffee district of Campinas and the mountains of Poços de Caldas near the southernmost edge of the state of Minas Garaes. The region proved to be too well cultivated for good rust collecting, although ten days were occupied, and 47 specimens obtained, 12 being on grasses.

The second notable outing, occupying about a month, was to Campos do Jordão (alt. 6,000 feet), and to the Government Forestry and Meteorological Stations on the slopes of Mt. Itatiaya, reputed to be 2,800 meters and the highest mountain in Brazil. The region is about 50 miles west of São Paulo. On April 24 with Mrs. Holway he walked to the summit of Mt. Itapevá, 1,948 meters altitude. Four days later, still at Campos do Jordão, he wrote: "Blew in at dark from an all-day hike, loaded with rusts, but soaked with rain and covered with red clay. The trip here is a profitable one, if only for the four fine grass rusts, which I am especially interested in."

They arrived on May 5 at the Forestry Station, officially known as Reserva Florestal, and for which a special permit is required, and remained five days. The experiences here were the most interesting and diverting of the whole year's trip. I can not refrain from quoting a few sentences from letters, especially to illustrate the unbounded enthusiasm of Professor Holway, his intense love of the work he was doing, and some of the experiences of a zealous collector of rusts. "May 9, 1922. A glorious hurricane in the mountains yesterday: trees crashing down the mountain sides, and branches flying through the air. Finally they began falling across my trail, and I beat it. So no rusts. Today was still and splendid, and I put a hunk of bread in my pocket, and was out until dark, coming in

with a lot of fine stuff, including one of the finest new grass rusts that I have seen." The next day he "did the twelve miles to the Meteorological Station, 4.200 feet up, in $5\frac{1}{2}$ hours, collecting on the way. Returned in 2 hours and 45 minutes, in a dense fog, the trail deep in mud, and vegetation dripping!!! And the doctors advised putting me in cotton wool, and sticking me into an incubator—or about that!" The collecting went on, however, for a week, and then with Mrs. Holway the ascent of Mt. Itatiaya was accomplished. The summit of the mountain "proved to be an imposing pile of gneiss, with a most remarkable chimney of some 200 meters, in which for an hour we did all sorts of stunts—standing on the guide's shoulders, crawling through S-shaped narrow holes on our sides, etc. The day was perfect and the view extensive and very fine." During the month in the mountains 129 collections were made, 19 being grass rusts.

After leaving the Forest Reserve they returned to São Paulo for a month in order to collect telia for the grass and other rusts, which were only showing uredinia earlier in the season. About a week was then taken to visit Curityba, the capitol of the state of Parana, and the vicinity, some 300 or more miles to the southwest, requiring the use of a coastwise steamer. The results, however, were disappointing, only ten rusts being obtained, of which three were grass rusts.

Returning to São Paulo the latter part of June some twenty-three collections were made during the two weeks following, only two being grass rusts. Although earlier in the month he had written, "both in perfect health," yet now time had to be counted out for illness, which although not alarming at first was the fore-runner of the series of bodily complications that resulted in the termination of all activity nine months later. It was now the midwinter season. "The days were warm and lovely," but the nights were cool. On July 7 he wrote from Guaraja on the seacoast near Santos: "São Paulo has a splendid winter climate, if only the hotels had heating; a temperature of 54° in our room night and morning was more than we could stand. I caught the worst cold I ever have had."

On July 25 passage was taken on a Holland steamer from Santos

to Montevideo, capitol of Uruguay. Here only one rust collection was secured, which was on a grass, and in a few days they went to Buenos Aires, capitol of Argentina. The only notable incident of the stay in this large and beautiful city was a visit to that most distinguished mycologist and general botanist of South America, Dr. Carlos Spegazzini of La Plata, and in a few days it was decided to go to a mountain resort, both for ready access to open territory in which to collect, and for the benefit of Professor Holway's health.

On the way to the mountains a day's stop was made at the ancient city of Cordoba, with its three-century old University and its thousand students. Here a few collections were made, aecia on *Stipa* being abundant in the city park.

About a fortnight followed at "La Falda," an attractive health resort in the western part of Argentina, where reasonable modern comforts were obtainable, and "real mountain air." Having been told it was a wild region, he was disappointed to find "there was not an inch of wild land. The hotel is on an estancia where the cattle eat the mountain tops bare as a board." Before leaving he decided, however, that although it was winter and not a grass to be found in flower, yet there were indications of a rich rust flora, particularly as to grass forms, and especially on numerous species of *Stipa* and related genera. There were 28 rust collections made here, including 14 on grasses and one of aecia on an alternate host.

One of the keen regrets attending the eastern South American trip was the necessity of omitting a visit to Paraguay, owing to the repeated revolutions in that country, which rendered travel there difficult and hazardous. As Paraguay could not be visited, and as the west coast could not readily and safely be reached in midwinter, it was decided to return to the United States. On August 31, 1922, the SS. *American Legion* was boarded at Buenos Aires, which landed the travellers in New York on September 25.

Results of the Eastern Exploration.

Over a thousand collections of rusts, including 182 on grasses, and six on alternate aecial forms, were obtained on this southern visit. Beside these there were brought back many hundreds of collections of flowering plants, partly for the purpose of making

certain the host determinations of the rusts, and partly to supply material for the study of difficult genera. The collections of *Mikania* and *Eupatorium* were subsequently sent to Dr. B. L. Robinson of the Gray Herbarium, and most of the other material to the National Herbarium at Washington, where Dr. F. S. Blake has studied some of the composites, Professor A. S. Hitchcock and Mrs. Agnes Chase all of the grasses, and other specialists have dealt with certain parts of the collections. All who have examined the material supplied by Professor Holway have spoken of the high quality, beauty and completeness of the specimens.

Acknowledgment of Assistance.

Many persons became interested in the work undertaken by the Holways, and gave very material assistance. Those in the Andean region to whom Professor Holway desired especially to record his appreciation were in Chile, Col. Alexander W. Chilton, U. S. Military Attaché, and Messrs. Sorrensen, Jones and Grant, of the Braden Copper Co.; in Bolivia, Ernesto Günther in particular, and Geo. W. Schneider, both of Sorato, Moises and Alfredo Ascarrunz, the former the Bolivian Statistician and the latter a Deputado (Representative), and Rafael Taborgo, a Deputado, for letters to the managers of their haciendas, to Manuel Balivian, also to the botanist, H. Buchtien, all of La Paz; in Ecuador, H. Ramel, who gave them the freedom of his home for eight days, and Frederick Tabel, both of Cuzco, Charles Cartwright and Geo. W. Powell of Guayaquil, Leo O. Kellogg of Portovelo, Charles Hartman, the American Minister, L. Söderstrom, the Swedish consul, all of Quito, and Edward Morley of Huigra.

In the eastern region the need of special assistance was not so great. While in Brazil, courtesies were extended by Dr. Eug. Rangel of the Jardim Botanico, Rio de Janeiro; Mr. A. Hempel of the Instituto Agronomico, Campinas; Professor P. H. Rolfs of the Agricultural College, Bello Horizonte; Dr. Hoehne of the Instituto Butantán, São Paulo; and in Argentina by Dr. C. Spegazzini, La Plata.

The generous assistance also rendered the writer by Dr. Spegazzini, who loaned many original collections for study, is most

gratefully acknowledged. Without such aid the comprehensive scope of this article would have been much impaired. In like manner the assistance given by the eminent specialists, Professor A. S. Hitchcock and Mrs. Agnes Chase, in identifying the hosts has been invaluable. They not only determined such specimens as were accompanied by inflorescence, but rendered opinions regarding many fragments of leaves and stems.

Earlier Collectors of Grass Rusts.

The earliest mycological collectors in the Andean region were Colla, Bertero and Gay, who collected in Chile about 1850, and whose material was largely studied by Montagne and Léveillé. The extent and importance of the results have made their work classical, but only one grass rust was included, a cosmopolitan form on *Phragmites*. During 1890 and 1891 Lagerheim collected in Ecuador, chiefly about Quito, reporting three well known grass rusts, his material being studied in part by Patouillard. In 1895 and 1896 Neger collected in Chile, especially in the vicinity of Concepción, and added some eight species to the Andean list of grass rusts, three being described as new, and also a new variety for one of them, the taxonomic work being in part done by Dietel. In 1909 Spegazzini, the well-known mycologist of Argentina, spent some time collecting in south-central Chile, between Santiago and Valdivia, securing four grass rusts, two of them being additions to the Andean list. In 1912 Mayor, a Swiss mycologist, reported six additional names for the Andean grass rusts, one being described as a new species. These were collected in the higher mountainous region of the central part of Colombia. In 1914 collections were made chiefly in Peru by Dr. and Mrs. Rose, and reported by the writer, which added one grass rust to the Andean list, and one other credited to Peru, but from the Amazonian region. One additional grass rust was recorded from Peru by Hennings as a part of a miscellaneous lot by various collectors.

Summarizing the preceding, it appears that previous to this paper there had been recorded for Chile 16 grass rusts, for Colombia 6, for Ecuador 3, for Peru 2, and for Bolivia none, in all making 27 names. Allowing for duplication of names, and for synonyms, there would be 20 species.

The attempt has not been made to ascertain in detail the collectors who have contributed to the knowledge of grass rusts east of the Andes, or the extent of their contributions. The name that stands prëeminent is that of the distinguished South American botanist, Dr. Carlos Spegazzini of La Plata, who gave particular attention to Argentina, Uruguay and Paraguay. For nearly half a century he has critically observed, described and recorded plants of all classes, and particularly the fungi. One sixth of the names in the present list of 74 species stands to his credit, and as many more names were given to species described by him that have since been identified with earlier names. His publications are numerous, and in any account of the development of knowledge regarding the South American flora will always be of the greatest value. Next to Dr. Spegazzini in the number of collections of fungi, especially the microforms, comes the German explorer, Dr. E. Ule of Berlin, who devoted himself particularly to Brazil, both the northern and southern parts. His material was largely described by Dr. P. Hennings of the Berlin Museum. None other of the many who have collected the smaller fungi has approached the volume of material supplied by Drs. Spegazzini and Ule.

Value of Seven League Boots.

In the number of collections of South American grass rusts, as well as in the value of the same, those made by Professor Holway much exceed the combined contributions of all previous collectors. In this regard he succeeded in carrying out his ambition to secure "the greatest collection of grass rusts ever made" on the southern continent. He knew how this was to be accomplished, for in one of his letters he wrote: "The only way one gets a collection is to keep his seven league boots on all the time." Of the two thousand collections of rusts which were brought back from the two South American trips, one fourth were grass forms. Of the 74 species of the following list, recognized as certainly occurring in South America, five sixths of them are represented in the Holway collections, and of the 225 species of grasses listed as hosts (belonging to 76 genera) more than one half are so represented.

In fact, the Holway rust collections on grasses add to the South

American flora 27 species, 12 of them being described as new, together with 116 hosts. Most of the species and hosts heretofore credited to South America not in the Holway collections were from areas not visited by the Holways, such as the more northern and more southern parts of the continent.

Aids to Thorough Work.

The intimate knowledge of flowering plants, which formed a background for Professor Holway's study of the rusts, renders his material more than usually valuable. He collected as good a phanerogamic specimen as possible to represent the host of every rust collection. In the determination of the grass hosts he had the invaluable assistance of the eminent grass specialists, Dr. A. S. Hitchcock and Mrs. Agnes Chase of the United States Bureau of Plant Industry. He also collected many interesting flowering plants, which supplied the basis for many new species by various specialists. When feasible duplicate material of both rusts and flowering plants was taken to be used for exchange and to distribute to special students.

In order to aid in carrying on the field work a microscope, typewriter, photographic outfit and plant press were always part of the supplies. The collections and instruments, together with necessary dryers, made an amount of impedimenta that was troublesome to care for and expensive to transport, all costs being borne from private funds.

The periods following the two excursions to South America were devoted to the assortment of the collections and also to their careful study. A number of the new species were detected by Professor Holway, for which he suggested names and pointed out their salient characters. He also supplied many valuable notes, and provided the photographs used in this article, and many others.

His constant ambition was to make a more complete study of rusts and their hosts in the various regions visited, and he was constantly planning other and more extensive and intensive explorations. He rarely spoke of any physical inhibition, but in a letter of December, 1921, being at the time in perfect health, he wrote: "Likely this is my last long collecting trip. I feel a little aged

sometimes. Hard luck, isn't it, just when one is free to do as he pleases!"

Survey of South American Grass Rusts.

In studying the very large set of grass rusts brought together by the Holways I have taken into account, so far as possible, all other collections of this sort recorded from South America, and also some additional ones that are in the Arthur Herbarium at Lafayette, Indiana, not previously mentioned in print.

Collectors have been gathering specimens of rusted grasses from various parts of South America between Trinidad and Cape Horn for three quarters of a century, and depositing them in European and American herbaria. A bibliography follows, which is fairly complete, and shows how much of this work has received attention and has been made public by published records.

Much of the material listed in the bibliography I have been able to examine through the kindness of mycological friends. My comments on these records are to be found under the various species treated. They can also be located by means of the index, except such names as precede the systematic part.

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COLLECTIONS NOT STUDIED BY THE WRITER.

There are a number of collections recorded under the old names of *Puccinia rubigo-vera*, *P. sessilis*, *P. straminis*, etc., which I have not seen, and which can not be accurately placed without micro-

scopic study. These when examined may add additional hosts and localities.

There is a collection recorded (Bol. Acad. Nac. Ci. Córdoba **25**:38. 1921) of *Puccinia simplex* on *Hordeum distichum*, which might be considered an addition to the list of species given below. It was secured by Dr. Spegazzini in the cultivated fields of the estate "Los Perales" near Santiago in the spring of 1917. Still another collection, made by C. Galander in Argentina, may represent an addition to the flora. It is cited in Sydow's Monog. Ured. **1**:724 (1903) under *Puccinia versicolor* Diet. & Holw. Neither of these collections has been seen by the writer.

There are still six additional names which may represent species not mentioned in the list below, but of which I have seen no material and am unable to reach a satisfactory opinion regarding their validity.

Puccinia pseudophacospora Speg. (An. Mus. Nac. Hist. Nat. Buenos Aires **31**:383. 1922) on *Cenchrus tribuloides*, Recoleta, Asunción, Paraguay.

Uredo dactylocteniicola Speg. (l. c. 392) on *Triticum durum*, Tucumán, Paraguay.

Uredo lejoderma Speg. (l. c. 396) on *Triticum durum*, Tucumán, Paraguay.

Uredo Syntherismae Speg. (l. c. 398) on *Panicum sanguinale*, Asunción, Paraguay.

Uredo uromycoides Speg. (An. Mus. Nac. Buenos Aires **6**:240. 1898) on *Panicum Phyllanthi*, La Plata, Argentina.

Uromyces chubutensis Speg. (An. Mus. Nac. Buenos Aires III. **1**:60. 1902) on *Poa chubutensis*, Carren-leofu, Argentina.

Keys and Indices.

A key to the species and an index both to rusts and their hosts have been added to the systematic account of species. It is hoped that these aids will be materially helpful to students, and especially to those persons who undertake further collections of this character. New species and new combinations are printed in broad-face type. The Roman numerals I, II, III, stand for aecial, uredinial and telial stages, while O stands for pycnia. When in lower case (small) letters

they indicate that only a scanty amount of that stage is present. Synonyms are printed in *Italics*, and new names and combinations in broad-face type.

KEY TO SPECIES.

Teliospores two-celled.
  Uredinia present *A*.
    A. Telia long covered by the epidermis *B*.
      B. Urediniospore-wall pale or colorless, thin, the pores obscure; paraphyses none or hyphoid *C*.
        C. Urediniospore-wall echinulate.
          Telia on *Zea* .... 1. *Puc. pallescens.*
          Telia on *Chaetochloa* .... 2. *Puc. Cameliae.*
          Telia on *Brachypodium* .... 3. *Puc. subdigitata.*
          Telia on *Festuca* .... 4. *Puc. mellea.*
          Telia on *Agropyron* and *Hordeum* .... 5. *Puc. glumarum.*
        C. Urediniospore-wall verrucose.
          Telia on *Paspalum* .... 6. *Puc. compressa.*
      B. Urediniospore-wall colored, echinulate *D*.
        D. Paraphyses none or hyphoid; urediniospore-wall echinulate *E*.
          E. Urediniospore-pores equatorial.
            Telia on *Cenchrus* .... 7. *Puc. Cenchri.*
          E. Urediniospore-pores scattered.
            Telia on *Avena*, *Hordeum*, *Lolium* and *Torresia* .... 8. *Puc. coronata.*
            Telia on *Agropyron*, *Briza*, *Bromus*, *Calamagrostis*, *Festuca*, *Hordeum*, *Poa*, *Trisetum* and *Triticum* .... 9. *Puc. Clematidis.*
            Telia on *Bromus*, *Hordeum* and *Lolium* .... 10. *Puc. cryptica.*
        D. Paraphyses clavate or capitate *F*.
          F. Urediniospore-pores equatorial.
            Telia on *Olyra* .... 11. *Puc. phakopsoroides.*
          F. Urediniospore-pores scattered.
            Telia on *Aira*, *Calamagrostis* and *Poa* .... 12. *Puc. Poarum.*
            Telia on *Bromus* and *Elymus* .... 13. *Puc. montanensis.*
    A. Telia early, or somewhat tardily naked *G*.
      G. Urediniospore-wall pale or colorless, the pores obscure; paraphyses none or hyphoid *H*.
        H. Urediniospore-wall echinulate *I*.
          I. Urediniospore-wall thick, and thicker above.
            Telia on *Chloris* .... 14. *Puc. Chloridis.*

I. Urediniospore-wall evenly thin.
Telia on *Olyra* .... 15. *Puc. deformata.*
Telia on *Arundinaria* and *Olyra* ... 16. *Puc. Bambusarum.*
Telia on *Tricuspis* .... 17. *Puc. guaranitica.*
Telia on *Ichnanthus* and *Oplismenus* .... 18. *Puc. inclita.*
Telia on *Pasaplum* .... 19. *Puc. macra.*
H. Urediniospore-wall verrucose, thick.
Telia on *Trachypogon* .... 20. *Puc. Trachypogonis.*
Telia on *Paspalum* and *Valota* (*Panicum*) .... 21. *Puc. panicophila.*
G. Urediniospore-wall colored *J.*
J. Paraphyses none or hyphoid *K.*
K. Urediniospore-wall echinulate *L.*
L. Urediniospore-pores equatorial.
Telia on *Eriochloa* and *Paspalum* .... 22. *Puc. substriata.*
Telia on *Panicum*, *Paspalum*, *Syntherisma* and *Valota* .... 23. *Puc. tubulosa.*
Telia on *Axanopus*, *Chaetochloa*, *Oplismenus*, *Panicum*, *Paspalum*, *Pennisetum* and *Tricholaena* .... 24. *Puc. levis.*
Telia on *Panicum* .... 25. *Puc. negrensis.*
Telia on *Agrostis*, *Bromus*, *Calamagrostis*, *Elymus*, *Hordeum*, *Lolium*, *Poa*, *Polypogon*, *Trisetum* and *Triticum* .... 26. *Puc. graminis.*
Telia on *Chloris* .... 27. *Puc. cacabata.*
Telia on *Phragmites* .... 28. *Puc. Phragmitis.*
Telia on *Piptochaetium* .... 29. *Puc. Piptochaetii.*
Telia on *Poa* .... 30. *Puc. subandina.*
Telia on *Zea* .... 31. *Puc. Sorghi.*
L. Urediniospore-pores scattered.
Telia on *Andropogon* .... 32. *Puc. variospora.*
Telia on *Aegopogon* .... 33. *Puc. Aegopogonis.*
Telia on *Polypogon* .... 34. *Puc. Polypogonis.*
Telia on *Agrostis* .... 35. *Puc. Moyanoi.*
Telia on *Bouteloua* .... 36. *Puc. vexans.*
Telia on *Eriochloa* and *Panicum* 37. *Puc. flaccida.*
Telia on *Sporobolus* .... 38. *Puc. hibisciata.*
Telia on *Trichloris* .... 39. *Puc. Trichloridis.*
Telia on *Hordeum* .... 40. *Puc. tornata.*
K. Urediniospore-wall verrucose *M.*
M. Urediniospore-pores equatorial.
Telia on *Panicum*, *Paspalum*, *Pennisetum* and *Valota* .... 41. *Puc. atra.*
Telia on *Aristida* and *Distichlis*. 42. *Puc. subnitens.*
Telia on *Capriola* (*Cynodon*)... 43. *Puc. Cynodontis.*

M. Urediniospore-pores scattered.
Telia on *Bouteloua* .... 44. *Puc. Opuntiae.*
Telia on *Chaetochloa* (*Setaria*).. 45. *Puc. Setariae.*
Telia on *Leptochloa* .... 46. *Puc. Leptochloae.*
Telia on *Melica* .... 47. *Puc. melicina.*
J. Paraphyses clavate or capitate *N*.
N. Urediniospore-wall verrucose, with the pores scattered.
Telia on *Sorghastrum* (*Andropogon*) 48. *Puc. virgata.*
N. Urediniospore-wall echinulate *O*.
O. Urediniospore-pores equatorial.
Telia on *Andropogon*, *Cymbopogon*, *Erianthus* and *Imperata* .... 49. *Puc. Kaernbachii.*
Telia on *Holcus* (*Sorghum*).... 50. *Puc. purpurea.*
Telia on *Pappophorum* and *Pennisetum* .... 51. *Puc. Gymnotrichis.*
O. Urediniospore-pores scattered.
Telia on *Bromus* .... 52. *Puc. decolorata.*
Telia on *Nasella* and *Stipa* .... 53. *Puc. Nasella.*
Telia on *Nasella* and *Stipa* .... 54. *Puc. digna.*
Uredinia unknown, probably not formed.
Aecia and telia on *Nasella* and *Stipa* .... 55. *Puc. graminella.*
Aecia on Malvaceae, telia on *Nasella* and *Stipa*. 56. *Puc. interveniens.*
Aecia unknown, telia on *Gymnopogon* .... 57. *Puc. Gymnopogonis.*
Teliospores one-celled *A*.
A. Telia long covered by the epidermis *B*.
B. Urediniospore-wall pale or colorless, echinulate, thin, the pores obscure.
On *Paspalum* .... 58. *Urom. paspalicola.*
B. Urediniospore-wall colored, echinulate, the pores discernible, equatorial.
On *Chaetochloa*, *Lasiacis*, *Panicum* and *Syntherisma* .... 59. *Urom. leptodermus.*
On *Microchloa* .... 60. *Urom. Microchloae.*
On *Nasella* or *Stipa* .... 61. *Urom. argentinus.*
A. Telia early or somewhat tardily naked *C*.
C. Urediniospore-wall colored or colorless, echinulate *D*.
D. Urediniospore-pores equatorial.
On *Sporobolus*, spores smaller .... 62. *Urom. ignobilis.*
On *Sporobolus*, spores larger .... 63. *Urom. Sporoboli.*
On *Andropogon* .... 64. *Urom. Andropogonis.*
D. Urediniospore-pores scattered.
On *Epicampes* .... 65. *Urom. Epicampis.*
On *Eragrostis* .... 66. *Urom. Eragrostidis.*
On *Bromus* .... 67. *Urom. bromicola.*
On *Nasella* and *Stipa* .... 68. *Urom. pencanus.*
On *Festuca*, *Melica* and *Muhlenbergia* .... 69. *Urom. fuegianus.*

Teliospores unknown.
Urediniospore-wall colorless, thin (1–1.5 μ).
Urediniospores globoid (on *Poa*) . . . . 70. *Uredo poiophila.*
Urediniospores ellipsoid or obovoid (on *Bambos*). 71. *Uredo ignava.*
Urediniospore-wall colored, thick (2–3 μ), echinulate.
Urediniospore-pores equatorial (on *Andropogon*). 72. *Uredo rubida.*
Urediniospore-pores scattered (on *Chaetochloa*) . . 73. *Uredo Setariae.*
Urediniospore-wall colored, thick (2–3 μ), verrucose. 74. *Uredo Panici-Urvilleanum.*

1. Puccinia pallescens Arth. Bull. Torrey Club **46**: 111. 1919.
Uredo pallida Diet. & Holw.; Holway, Bot. Gaz. **24**: 37. 1897.

Collections of this rust were made in two localities on the Island of Trinidad in 1921, on *Zea Mays* L., by Seaver *3103, 3110* (Mycologia **14**: 18. 1922). No other South American collections are known. Telia have only once been detected. They were found on *Tripsacum latifolium* from Nicaragua, and are very inconspicuous.

2. Puccinia Cameliae (Mayor) Arth., Mycologia **7**: 227. 1915.
Uredo Cameliae Mayor, Mém. Soc. Neuch. Sci. **5**: 578. 1913.
Dicaeoma Cameliae Arth. & Fromme, N. Am. Flora **7**: 293. 1920.

Chaetochloa scandens (Schrad.) Scribn. & Merr. (*Setaria scandens* Schrad.), São Joán, São Paulo, Brazil, July 2, 1922, II, III, *1989*.

This rust was first found in Colombia on the same host, and it also occurs in the West Indies and in southern Texas.

3. Puccinia subdigitata Arth. & Holw.; Arth. Am. Jour. Bot. **5**: 468. 1919.
Dicaeoma subdigitatum Arth. & Fr. N. Am. Flora **7**: 340. 1920.
Solenodonta subdigitata Sydow, Ann. Myc. **19**: 174. 1921.

Brachypodium mexicanum (R. & S.) Link, Cochabamba, Bolivia, February 28, 1920, II, *346*; same, March 14, 1920, II, *409*; Sorata, Bolivia, April 18, 1920, II, *544*.

This species has heretofore been known only from Guatemala, the type collection being made by Professor Holway.

4. Puccinia mellea Diet. & Neg., Bot. Jahrb. **24**: 155. 1897.

Festuca eriolepis Desv., Maipo Valley near Santiago, Chile, Oct. 2, 1919, III, *80*; Lorrain Alcalde, Chile, Oct. 11, 1919, III, *105*.

Festuca megalura Nutt., Viña del Mar, Chile, September 8, 1919, III, *15*; same, September 14, 1919, III, *23*: Lorrain Alcalde, Chile, October 11, 1919, II, *103*; Constitucion, Chile, October 17, 1919, III, *122*; Valdivia, Chile, November 14, 1919, II, III, *177*.

Festuca Myuros L., Papudo, Chile, Sept. 17, 1919, III, *31*.

The type collection, which has been examined by the writer, is said to be on *Festuca muralis*. The rust has not been reported outside of Chile.

5. PUCCINIA GLUMARUM (Schmidt) Erikss. & Henn. Zeits. Pflanzenkr. 4: 197. 1894.

Dicaeoma glumarum Arth. & Fr. N. Am. Flora, **7**: 338. 1920.

Agropyron attenuatum R. & S., Riobamba, Ecuador, August 11, 1920, II, iii, *869*.

Hordeum chilense R. & S., Vinā del Mar, Chile, September 6, 1919, II, *9*.

This is the first report of the occurrence of *Puccinia glumarum* in South America, and it is significant that these collections are from the west side of the Andes. In North America it occurs in the mountainous region of the western part, but not eastward of the Rocky Mountains.

6. Puccinia compressa Arthur & Holway sp. nov.

Paspalum elongatum Griseb., Cochabamba, Bolivia, February 26, 1920, II, *331*; same II, III, *331½* (type); same, March 12, 1920, II, *403*; Sorata, Bolivia, April 14, 1920, II, *516*.

O and I. Pycnia and aecia unknown.

II. Uredinia amphigenous, scattered, oblong or elongate-oblong, 0.3–1 mm. long, early naked, somewhat pulverulent, brownish-yellow, the ruptured epidermis and paraphyses forming a moderately conspicuous border; paraphyses numerous, peripheral, incurved and appearing spatulate, hyphoid, short, about 6 by 35 μ, the wall colorless, thickened on the convex side, smooth; urediniospores ellipsoid or obovate, 15–22 by 20–28 μ; wall colorless or nearly so, thin, 1–1.5 μ, closely and finely verrucose or echinulate-verrucose, the pores obscure.

III. Telia amphigenous, scattered, oblong, 0.2–0.5 mm. long, long covered by the epidermis, blackish-brown, prominent; teliospores compactly adhering laterally, 12–14 by 50–55 μ, rounded or

truncate above and below, strongly constricted at septum; wall chestnut-brown, very thin, 0.5 μ or less, much thickened and darker above, 3–5 μ, with an additional outer, colorless or pale yellow layer of equal thickness, smooth; pedicel very short or wanting.

This species is closely allied in its morphological characters, to *Puccinia phakopsoroides*, but differs noticeably in most of the details. As in that species there is no stromatal layer around the telial sorus. The hyaline apex to the teliospores is readily seen without staining

FIG. 1. Teliospores of *Puccinia compressa* on *Paspalum* (collection *331½*). Note the transparent outer layer of the upper part of each spore. × 500.

(Fig. 1). The deep color of the telia resides in the spores, and is not due to the host tissue. The teliospores are uniformly two-celled, but each of the two cells is rounded off at the ends as if it were an independent spore.

7. PUCCINIA CENCHRI Dietel & Holway; Holway, Bot. Gaz. **24**: 28. 1897.

Dicaeoma Cenchri Arth. Résult. Sci. Congr. Bot. Vienne 344. 1906.

Uredo cenchrophila Speg. An. Mus. Nac. Buenos Aires **19**: 316. 1909.

Cenchrus echinatus L., Piassaguera near Santos, Brazil, February 9, 1922, II, *1549*.

The type collection of *Uredo cencrophila* has been examined by the writer, through the courtesy of Señor Spegazzini, and found to agree perfectly with other collections of this species.

The species has also been reported on *C. echinatus* from Copacabana, Rio de Janeiro, Brazil, Ule *2549* (Dietel, Hedwigia **38**: 249. 1899), and from Colombia, Mayor *154* (Mém. Soc. Neuch. Sci. Nat. **5**: 472. 1913).

8. PUCCINIA CORONATA Corda, Ic. Fung. **1**: 6. 1837.
Aecidium Rhamni Pers. in J. F. Gmel. Syst. Nat. **2**: 1472. 1791.
Puccinia Lolii Nielsen, Ugeskr. Landm. **1875**[1]: 549. 1875.
Puccinia Rhamni Wettst. Verh. Zool.–Bot. Ges. Wien **35**: 545. 1886.
Puccinia coronifera Kleb. Zeits. Pflanzenkr. **4**: 135. 1894.
Dicaeoma Rhamni Kuntze, Rev. Gen. **3**[2]: 470. 1898.
Solenodonta coronata Sydow, Ann. Myc. **19**: 174. 1921.

Avena barbata Brot. (*A. hirsuta* Moench.) Viña del Mar, Chile, September 6, 1919, II, III, *6, 8½*; same, September 16, 1919, II, *24*; Santiago, Chile, September 29, 1919, II, III, *75*; Temuco, Chile, November 1, 1919, II, *157*; Puerto Varas, Lago Llanquihue, Chile, November 26, 1919, II, *187*; Panimavida, Chile, December 10, 1919, II, III, *213*.

Avena fatua L., Sorata, Bolivia, April 13, 1920, II, *513*.

Avena sativa L., Temuco, Chile, November 3, 1919, II, III, *158*; Puerto Varas, Chile, November 20, 1919, II, *179*; Linares, Chile, December 23, 1919, II, III, *248*; La Paz, Bolivia, March 23, 1920, II, III, *445*; Friburgo, Rio de Janeiro, Brazil, January 2, 1922, II, III, *1447*.

Hordeum murinum L., Viña del Mar, Chile, September 7, 1919, II, iii, *13*.

Lolium perenne L., Constitucion, Chile, October 15, 1919, II, iii, *119*; Valdivia, Chile, November 13, 1919, II, *172*; Peulla, Lago Todas los Santos, Chile, November 29, 1919, II, *191*; Parque San Martin, Córdoba, Argentina, August 10, 1922, II, III, *2017½*.

Lolium temulentum L., San Felipe, Chile, September 25, 1919, II, *71*.

Lolium sp., Lorrain Alcalde, Chile, October 11, 1919, II, iii, *102*.

Torresia redolans (Vahl) R. & S., Walls of Spanish Fort, Corral, Chile, November 12, 1919, II, *168*.

The species is also recorded on *Avena sativa* from Quito, Ecuador (Bull. Soc. Myc. France **7**: 169. 1891), and from S. Juan, Argentina

(An. Mus. Nac. Buenos Aires III, **1**: 61. 1902); on *Avena hirsuta* from La Plata, Argentina (Speg. An. Mus. Nac. Buenos Aires **6**: 220. 1899; Fungi Chil. 19. 1910); on *Avena fatua* from La Plata, Argentina (An. Mus. Nac. Buenos Aires **6**: 220. 1899); and on *Lolium perenne* from La Plata, Argentina (An. Mus. Nac. Buenos Aires **19**: 297. 1909).

9. PUCCINIA CLEMATIDIS (DC.) Lagerh. Tromsö Mus. Aarsh. **17**: 54. 1895.

Aecidium Clematidis DC. Fl. Fr. **2**: 243. 1805.

Uredo rubigo-vera DC. in part. Fl. Fr. **6**: 83. 1815.

Puccinia Elymi Westend. Bull. Acad. Brux. **18**[2]: 408. 1851.

Puccinia rubigo-vera Wint. in part, in Rab. Krypt. Fl. **1**[1]: 217. 1881.

Puccinia Agropyri Ellis & Ev. Jour. Myc. **7**: 131. 1892.

Puccinia triticina Erikss. Ann. Sci. Nat. VIII, **9**: 270. 1899.

Puccinia brachypus Speg. An. Mus. Nac. Buenos Aires III, **1**: 61. 1902.

Puccinia Triticorum Speg. An. Mus. Nac. Buenos Aires III, **1**: 65. 1902.

Uredo auletica Speg. An. Mus. Nac. Buenos Aires III, **1**: 65. 1902.

Dicaeoma Clematidis Arth. Résult. Sci. Congr. Bot. Vienne 344. 1906.

Clematis dioica L., Quito, Ecuador, August 13, 1920, O, I, *879*.

Agropyron attenuatum R. & S., La Paz, Bolivia, March 19, 1920, II, III, *427*.

Briza Calotheca (Trin.) Hack., Campos do Jordão, São Paulo, Brazil, alt. 1600 meters, April 28, 1922, II, iii, *1792*.

Briza Lilloi Parodi, Quito, Ecuador, August 29, 1920, II, *953*.

Briza stricta (Hook.) Steud., Pichilemu, Chile, October 12, 1919, II, *108*; Panamavida, Chile, December 17, 1919, II, *240*; Termas de Chillan, Chile, January 2, 1920, II, *268*; Cochabamba, Bolivia, March 8, 1920, II, III, *383*.

Bromus Buchtienii Hack., Cochabamba, Bolivia, March 8, 1920, ii, III, *382*.

Bromus coloratus Steud., Constitucion, Chile, October 18, 1919, III, *125*; Temuco, Chile, November 1, 1919, II, *156*; Walls of old

Spanish Fort, Corral, Chile, November 12, 1919, II, III, *171*; Puerto Varas, Lago Llanquiline, Chile, November 21, 1919, II, *181*; Railway between Oruro and Cochabamba, Bolivia, March 16, 1920, II, III, *415*; La Paz, Bolivia, March 20, 1920, II, III, *429*; Quito, Ecuador, August 14, 1920, II, *886*; same, August 18, 1920, II, *915*.

Bromus commutatus apricorum Simk., Pichilemu, Chile, October 12, 1919, II, *112*.

Bromus lithobius Trin., Panamavida, Chile, December 12, 1919, III, *222*.

Bromus pitensis H. B. K., Sorata, Bolivia, April 19, 1920, II, III, *552*.

Bromus stamineus Desv., Zapallar, Chile, February 1, 1920, ii, III, *308*.

Bromus unioloides H. B. K., San José de Maipo, Chile, October 5, 1919, II, *88*; La Paz, Bolivia, March 27, 1920, II, *471*; Quito, Ecuador, August 15, 1920, II, III, *901*.

Bromus sp., Quito, Ecuador, August 15, 1920, III, *904*; Córdoba, Argentina, August 11, 1922, II, III, *2019*; La Falda, Argentina, alt. 1,020 meters, August 14, 1922, II, *2029*; same, August 22, 1922, II, *2041*.

Calamagrostis heterophylla robustior Pilger, Sorata, Bolivia, April 29, 1920, II, *583*.

Festuca lasiorrhachis Pilger, Sorata, Bolivia, April 14, 1920, ii, III, *519*.

Festuca octoflora Walt., Panamavida, Chile, December 9, 1919, III, *212*.

Hordeum chilense R. & S., Panamavida, Chile, December 9, 1919, II, III, *208*.

Hordeum murinum L., San Felipe, Chile, September 25, 1919, II, III, *70*.

Poa androgyna Hack., La Paz, Bolivia, April 5, 1920, II, *496*; same, May 14, 1920, II, III, *606*.

Poa bonariensis Kunth, Papudo, Chile, September 20, 1919, II, III, *57*; Constitucion, Chile, October 15, 1919, II, III, *114*; same, October 18, 1919, II, III, *126*; Recinto, Chile, January 10, 1920, II, iii, *286*.

Poa pallens Poir., Papudo, Chile, September 17, 1919, II, III, *30*.

Trisetum spicatum (L.) Richt., La Paz, Bolivia, March 28, 1920, II, III, *478*.

Triticum aestivum L. (T. vulgare Vill.), Puerto Varas, Chile, November 18, 1919, II, *178A*; Panamavida, Chile, December 10, 1919, II, III, *214*.

Although this list of 22 hosts is much the longest known for any South American grass rust, yet in North America there are over 150 species of hosts known for this same rust. In the above list only one collection represents the aecial stage, while in North America over 60 species of hosts are known for this stage. It is possible that the species is not as abundant in the southern hemisphere as northward, and possibly when collected its identity has not been clearly recognized.

Through the courtesy of Señor Spegazzini the writer has been able to examine three South American collections, all from Argentina, which represent apparently three of the above synonyms. Two collections were cited when *Puccinia brachypus* Speg. was first published. The first of these, which may be considered the type, was collected at Rufino in November, 1900, on *Bromus auleticus*, and shows an abundance of covered telia with a few intermixed urediniospores. This packet had a line drawn through the specific name and "*auletica*" substituted in a different ink. I can not find that "Puccinia auletica" has ever been established as a species by Spegazzini, although it has been mentioned a number of times in literature, and would be a synonym in any case. In the same publication where the citation is given, but four pages further over, the name *Uredo auletica* Speg. is established, with the same host from the same locality but taken a month later. This collection I have not seen, but the description agrees perfectly with the uredinial part of the first collection.

The second host mentioned under *P. brachypus* is *Triticum sativum*, collected two years later than the first host and in a different locality. The spores agree exactly with those on the *Bromus*.

Puccinia Triticorum Speg. was established on a collection of *Hordeum compressum*, made on January 5, 1905, and shows both uredinia and telia. The teliospores are somewhat longer than in the other two collections, but otherwise the same. It doubtless repre-

sents a different race, as this rust is known to have a number of races with spores of somewhat different sizes, and presumably with aecia on different hosts of *Ranunculaceae*.

The species has been recorded on *Clematis bonariensis* Juss., and *C. Hilarii* Spreng. from Argentina (An. Mus. Nac. Buenos Aires **6**: 231. 1899); on *Clematis sericea* H. B. K. from Quito, Ecuador, on *Agropyrum glaucum* R. & S. from Ambato, Ecuador (Bull. Herb. Boiss. **3**: 63. 1895), on *Triticum durum* Desf. from Córdoba, Argentina (An. Mus. Nac. Buenos Aires, **19**: 297. 1909); on *Bromus Schraderi* Kunth, from Colonia Ceres, Argentina (An. Mus. Nac. Buenos Aires **19**: 297. 1909), under the name *Puccinia bromina;* and on *Triticum hybernum* L. and *T. turgidum* L. from Buenos Aires, Argentina (An. Mus. Nac. Buenos Aires **19**: 297. 1909), under the name *Puccinia triticina* Erikss.

It is highly probable that *Uredo Chascolythri* Diet. & Neg. (Bot. Jahrb. **27**: 15. 1899) may belong here, although the spores are said to be verrucose, the only character given that diverges from the usual description of the present species. The writer has not seen material of it. It was collected at Concepción, Chile, on *Chascolythrum trilobum* E. Desv., a synonym of *Briza triloba* Nees.

10. **Puccinia cryptica** Arthur & Holway sp. nov.

Bromus Trinii Desv., Papudo, Chile, September, 17, 1919, II, *29*; same, September 18, 1919, ii, III, *40* (type); same, September 19, 1919, II, III, *48, 54*; Puente Alto near Santiago, Chile, October 3, 1919, II, III, *84*; Constitucion, Chile, October 8, 1919, II, *96*; same, October 20, 1919; ii, III, *135*.

Lolium multiflorum Lam., Puente Alto near Santiago, Chile, October 3, 1919, II, *81*; San José de Maipo, Chile, October 8, 1919, II, *98*; Los Angeles, Chile, October 30, 1919, II, *151½*; Panamavida, Chile, December 12, 1919, II, III, *221*.

Lolium sp., Constitucion, Chile, October 20, 1919, II, III, *133*; Termuco, Chile, November 3, 1919, II, *161*; Recinto, Chile, January 10, 1920, II, III, *289*.

O and I. Pycnia and aecia unknown.

II. Uredinia amphigenous, evenly scattered without marked discoloration, oval or oblong, 0.3–0.8 mm. long, somewhat tardily

naked by a longitudinal slit of the epidermis, moderately pulverulent, pale cinnamon-brown or yellowish, the ruptured epidermis conspicuous; urediniospores broadly ellipsoid or globoid, 19–26 by 21–29 μ; wall pale- or brownish-yellow, 1–1.5 μ thick, finely echinulate, the pores scattered, 6–8, indistinct.

III. Telia epiphyllous, scattered, oval or oblong, 0.1–0.8 mm. long, long covered by the epidermis, blackish-brown; teliospores irregularly ellipsoid or obovate, 20–32 by 32–46 μ, sometimes with longer and narrower spores intermixed, truncate or obtuse above, more or less narrowed below, slightly or not constricted at septum; wall chestnut brown, 2–3 μ thick, thicker and darker above, 3–6 μ, smooth; pedicel very short, somewhat colored.

This species differs from the preceding one most strongly in the much broader and thicker-walled teliospores. It has been sent to me from the grass herbarium of the U. S. National Museum, on *Hordeum compressum* Griseb., collected by Ernest Gibson, at Buenos Aires, Argentina, without date.

11. PUCCINIA PHAKOPSOROIDES Arth. & Mains, Bull. Torrey Club 46: 412. 1919.

Dicaeoma phakopsoroides Arth. & Fromme, N. Am. Flora **7**: 295. 1920.

Olyra latifolia L., Portovelo, Prov. Oro, Ecuador, Sept. 23, 1920, II, III, *1002*.

This inconspicuous and curious grass rust, with its gelatinized outer layer to the teliospores, has been collected a number of times in Cuba and Porto Rico, but now for the first time in South America.

12. PUCCINIA POARUM Nielsen, Bot. Tidsskr. III. **2**: 34. 1877.

Lycoperdon epiphyllum L. Sp. Pl. 1185. 1753.

Puccinia epiphylla Wettst. Verh. Zool.-Bot. Ges. Wien **35**: 541. 1886.

Uredo Airae Lagerh. Jour. de Bot. **2**: 432. 1888.

Puccinia pygmaea Dietel, Hedwigia **36**: 29. 1897.

Puccinia exigua Dietel, Hedwigia **36**: 299. 1897.

Dicaeoma epiphyllum Kuntze, Rev. Gen. **3**^{3}: 468. 1898.

Uredo paulensis P. Henn. Hedwigia **41**: 297. 1902.

Ophryosporus venosissimus (Rusby) B. L. Robinson, Cochabamba, Bolivia, March 8, 1920, O, I, *381*; same, March 10, 1920, O, I, *391*.

Aira danthonioides Trin. (*Deschampsia danthonioides* Munro), Lorrain Alcalde, Chile, October 11, 1919, II, III, *100*.

Calamagrostis cajatambensis Pilger, La Paz, Bolivia, March 30, 1920, II, III, *484*.

Calamagrostis Fiebrigii Pilger, Cochabamba, Bolivia, March 8, 1920, II, III, *379*; same, III, *380*.

Calamagrostis montevidensis Nees, Therezopolis, Brazil, alt. 1050 meters, October 11, 1921, II, *1207*; São Joás, São Paulo, Brazil, March 19, 1922, III, *1649*; Campos do Jordão, São Paulo, Brazil, alt. 1600 meters, April 28, 1922, II, III, *1791*; Itatiaya, São Paulo, Brazil, alt. 2100 meters, May 18, 1922, II, *1858*; Garulhos, São Paulo, Brazil, II, III, June 1, 1922, *1935*; Jaragua near Taipas, Brazil, June 10, 1922, III, *1953*; Curityba, Parana, Brazil, alt. 900 meters, June 20, 1922, II, *1980*.

Poa annua L., Santiago, Chile, September 30, 1919, II, *76*; Viña del Mar, Chile, September 6, 1919, II, *7*; Corral, Chile, November 12, 1919, II, III, *170*; Summit of the pass, Oruro-Cochabamba Railway, Bolivia, March 16, 1920, II, *416*; La Paz, Bolivia, March 19, 1920, II, III, *421*; Quito, Ecuador, August 20, 1920, II, III, *929*; Petropolis, Brazil, alt. 700 meters, November 3, 1921, II, *1269*; Parque Sarmiento, Córdoba, Argentina, August 13, 1922, II, *2017*.

Poa bonariensis Kunth, Constitucion, Chile, October 17, 1919, II, *124*; Concepción, Chile, October 27, 1919, II, *143*; same, October 29, 1919, II, *146*; Termas de Chillan, Chile, January 5, 1920, II, *274*.

Poa pratensis L., San José de Maipo, Chile, October 6, 1919, II, *92*; Temuco, Chile, November 3, 1919, II, *155*; Puerto Varas, Lago Llanquihue, Chile, November 26, 1919, II, *186*.

Poa secunda Presl, San José de Maipo, Chile, October 8, 1919, II, *99*.

Relchela panicoides Steud., Temuco, Chile, November 5, 1919, II, *167*; same, Recinto, Chile, January 9, 1920, II, *277*.

A cosmopolitan rust, but forming teliospores sparingly. The aecia heretofore recognized have been on *Tussilago* and *Petasites* only, but there have been many reasons for thinking that other hosts would eventually be found. The observations of Professor Holway are dependable, and so far as morphological characters, isolation

and propinquity, without cultures, can establish genetic connection, there can be no doubt of the correctness of the present assignment, although the new aecial host is a near relative of *Eupatorium*, and the previously known aecial hosts belong to the tribe *Senecioneae*.

The rust is very common in South America on *Poa annua*. A form from Brazil with spores averaging somewhat smaller than usual was named *P. exigua* (*P. pygmaea*) by Dietel, *l. c.*

The rust occurs upon *Aira* in North America and Europe, but has not before been recognized upon *Calamagrostis*. Through the kindness of the curator of the Berlin Museum the writer has been able to examine the original collection of *Uredo paulensis*, which was found by Puttemans in December, 1901, in the Botanic Garden at São Paulo, Brazil. It shows the abundant and characteristic paraphyses, and spores with about 6 scattered pores.

Beside the above the following collections are in the Arthur Herbarium:

Agrostis magellanica Lam., Punta Arenas, Magellanes, Chile, II, III, February 22, 1906, R. Thaxter *60*; same, March, 1906, R. Thaxter *61*.

Poa annua L., Ambato, Ecuador, II, 1920, A. Pachano; La Plata, Argentina, II, October, 1905, R. Thaxter *79*.

Poa bonariensis Kunth, Buenos Aires, Argentina, II, R. Thaxter *89*.

Poa fuegiana (Hook) Hack., Punta Arenas, Magellanes, Chile, II, February, 1906, R. Thaxter *39*.

The first named collections add another host genus to the species. It will be noticed that they were obtained in two localities in the same region as the collection on *Poa fuegianus*, that both the *Poa* and *Agrostis* are endemic species, and furthermore that the *Agrostis* in both instances bears abundant telia, while the *Poa* has only uredinia.

13. PUCCINIA MONTANENSIS Ellis, Jour. Myc. **7**: 274. 1893.

Dicaeoma montanensis Kuntze, Rev. Gen. 3^2: 469. 1898.

Aecidium Fendleri Tracy & Earle in Greene Pl. Baker. **1**: 17. 1901.

Puccinia Fendleri Jackson, Brooklyn Bot. Gard. Mem. **1**: 246. 1918.

Pleomeris montanensis Sydow, Ann. Myc. **19**: 171. 1921.

Berberis sp., Termas de Chillan, Chile, December 28, 1919, I, *254*.

Bromus brachyanthera Döll., Serrinha, Parana, Brazil, June 19, 1922, II, *1973*.

Bromus coloratus Steud., Termas de Chillan, Chile, Jan. 2, 1920, II, *266*.

Bromus unioloides H. B. K., Termas de Chillan, Chile, January 3, 1920, II, iii, *271*.

Bromus valdivianus Phil., Termas de Chillan, Chile, December 29, 1919, II, iii, *257*.

Bromus sp., Constitucion, Chile, October 15, 1910, ii, III, *116*.

Elymus agropyroides J. & C. Presl, Termas de Chillan, Chile, January 5, 1920, II, III, *275*.

Elymus andinus Trin., Concepción, Chile, October 25, 1919, II, *137*; Termas de Chillan, Chile, January 2, 1920, II, III, *267*; Recinto, Chile, January 9, 1920, II, III, *276*; same, II, iii, 279, *283*.

Elymus sp., Termas de Chillan, Chile, December 31, 1919, II, *264*.

This rust is probably more common than the present collections indicate. The aecia on *Berberis* may have been reported a number of times under various names, but the few collections seen by the writer do not belong here.

The species, which adds a new name to the South American list, differs from *Puccinia epiphylla*, not only in having different aecial hosts, but in having less strongly developed paraphyses, and larger urediniospores and teliospores. The general habit of the rust is somewhat like that of *Puccinia glumarum* in its tendency to produce lines of sori on golden-yellow or pale stripes.

14. PUCCINIA CHLORIDIS Speg. Rev. Arg. Hist. Nat. **1**: 172. 1891.

Puccinia Chloridis Dietel, Hedwigia **31**: 290. 1892.

Dicaeoma Chloridis Kuntze, Rev. Gen. 3^3: 468. 1898.

Puccinia Dietelii Sacc. & Sydow; Sacc. Syll. Fung. **14**: 358. 1899.

Chloris distichophylla Lag., La Florida, Prov. Nor Yungas, Bolivia, May 29, 1920, II, III, *677*; San Roque, São Paulo, Brazil, March 21, 1922, II, III, *1661*.

The type collection of this species from Paraguari, Paraguay, has not been seen by the writer, but a collection has been examined from Passage, Argentina, which agrees perfectly with the rather detailed description. The latter collection is on *Chloris radiata* Sw. (*C. Beyrichiana* Kunth), and was made by Lorentz & Hieronymus, February, 1873. These records also agree with the numerous North American collections taken from Kansas to central Mexico. The rust reported under this name by Spegazzini in An. Mus. Nac. Buenos Aires **19**: 298 (1909), is not this species, but is given below under *P. cacabata*.

15. PUCCINIA DEFORMATA Berk. & Curt.; Berk. Jour. Linn. Soc. **10**: 357. 1869.

Dicaeoma deformatum Kuntze, Rev. Gen. 3^3: 468. 1898.

This distinctive species, occurring on *Olyra latifolia* L., was not taken by the Holways. The only collection known to me from South America was made by Seaver on Gasparee Island, near Trinidad, British West Indies, April, 1921 (Mycologia **14**: 17. 1922).

16. PUCCINIA BAMBUSARUM (P. Henn.) Arth. Bot. Gaz. **65**: 467. 1918.

Uredo Bambusarum P. Henn. Hedwigia **35**: 255. 1896.
Uredo Olyrae P. Henn. Hedwigia **43**: 164. 1904.

Olyra micrantha H. B. K., Paineiros, Brazil, August 17, 1921, II, *1047*; Rio de Janeiro, Brazil, August 29, 1921, II, III, *1077*; Petropolis, Brazil, alt. 850 meters, October 22, 1921, II, *1243*; Cascadura, Rio de Janeiro, Brazil, January 12, 1922, II, III, *1473*; Guaruja, Santos, Brazil, July 18, 1922, II, *2014*, II, III, *2018*; Reserva Florestal, Itatiaya, Brazil, May 10, 1922, II, *1840*.

The history of this species has been recorded by the writer in the Botanical Gazette for May, 1918 (**65**: 467–468); and the type collections of Hennings' *Uredo Bambusarum* and *U. Olyrae* have been examined. Both collections were made by Ule, the first in Peru, on *Arundinaria* sp. (not *Olyra*, as reported), and the second in Brazil, on *Olyra micrantha* (not *Arundinaria*, as stated in the Botanical Gazette *l. c.*). The first of these two collections was distributed in

Ule, App. Myc. Brasil. *5*. The species has also been taken in Brazil on *Olyra micrantha* by Eug. Rangel, July, 1913, and by F. Noack, October, 1897, the latter being distributed in Sydow, Uredineen *2097*.

17. PUCCINIA GUARANITICA Speg. An. Soc. Ci. Argent. **26**: 12. 1888.

This species was not taken by the Holways. It is known to the writer from the type collection only, which has been examined through the courtesy of Señor Spegazzini. It was collected by B. Balansa *3966*, at Guarapi, Paraguay, October, 1883, on *Tricuspis latifolia* Griseb. The species is a distinctive one, but only the one record of its occurrence has been found.

18. PUCCINIA INCLITA Arth. Bull. Torrey Club **46**: 115. 1919.

Dicaeoma inclitum Arth. & Fromme, N. Am. Flora **7**: 289. 1920.

Ichnanthus candicans (Nees) Döll., Reserva Florestal, Rio de Janeiro, Brazil, May 9, 1922, II, *1828*.

Ichnanthus glaber (Raddi) Hitchc. & Chase, Bosque da Saude, São Paulo, Brazil, January 31, 1922, II, *1521*.

Ichnanthus sp., Tijuca, Rio de Janeiro, Brazil, December 23, 1921, II, *1422*.

Oplismenus Minarum Nees, Sorata, Bolivia, April 17, 1920, II, III, *541*.

This species, which occurs in the West Indies, is now reported for the first time from South America. It is a remarkably distinctive species, especially in its urediniospores, which have a bristly echinulation. It will probably be found eventually on other hosts than those recorded above, the only ones so far known for the species.

19. PUCCINIA MACRA Arth. & Holw.; Arth. Am. Jour. Bot. **5**: 465. 1918.

Dicaeoma macrum Arth. & Fr. N. Am. Flora **7**: 287. 1920.

Paspalum candidum (Humb. & Bonpl.) Kunth, Villa Aspiazu, Nor Yungas, Bolivia, June 1, 1920, II, III, *697*.

Paspalum pallidum H. B. K., Quito, Ecuador, August 17, 1920, II, *909*; same, August 30, 1920, II, III *954*.

The type collection of the species was from Guatemala, on *Paspalum candidum*. The only South American collection heretofore known to the writer is in the Arthur Herbarium, and was made at Ambata, Ecuador, in 1920, by A. Pachano. It is on *P. pallidum*.

20. PUCCINIA TRACHYPOGONIS Speg. An. Mus. Nac. Buenos Aires **19**: 301. 1909.

This species was not taken by the Holways. The only record of it is by Spegazzini (*l. c.*), on *Trachypogon Montufari* (H. B. K.) Nees, from Argentina, two collections being made, the first one (type) being from Catamarca, January, 1903, and the second from La Rioja, July, 1904. Through the courtesy of Señor Spegazzini I have been enabled to examine both collections, which exhibit a distinctive species of rust, the type material showing both uredinia and telia. The urediniospores have thick colorless walls, in which the pores can not be made out.

21. PUCCINIA PANICOPHILA Speg. An. Mus. Nac. Buenos Aires **19**: 300. 1909.

This species was not taken by the Holways. The only record is that of the type collection, which was obtained on the mountains near Cacheuta, Argentina, February 26–27, 1908, and another from the same locality in 1909. The type material has been examined by the writer through the courtesy of Señor Spegazzini, and the host inspected by Professor A. S. Hitchcock of the National Museum.

The species is unusually distinctive on account of its thick-walled, colorless urediniospores, with four equatorial pores, and a very coarsely verrucose surface. The host was given on the original packet as "*Panicum penicillatum*," but when published was changed to *Panicum insulare* (*Valota insularis* (L.) Chase). It is considered by Professor Hitchcock to be more probably *Valota saccharata* (Buckl.) Chase, rather than *V. insularis*. A collection made by Lagerheim, at Quito, Ecuador, May, 1880, and distributed by him as a new species, but the name not published, appears to belong here. The host is accompanied by inflorescence, and has recently been determined by Professor Hitchcock as *Paspalum penicillatum* Hook.

22. PUCCINIA SUBSTRIATA Ellis & Barth. Erythea **5**: 47. 1897.

Uredo Panici P. Henn. Hedwigia **43**: 165. 1904.

Uredo Henningsii Sacc., Syll. Fung. **17**: 456. 1905.

Dicaeoma substriatum Arth. Résult. Sci. Congr. Bot. Vienne 344. 1906.

Uredo Eriochloae Speg. An. Mus. Nac. Buenos Aires **19**: 319. 1909. Not Sydow, 1906.

Uredo eriochloana Sacc. & Trott. in Sacc. Syll. Fung. **21**: 810. 1912.

Puccinia dolosa Arth. & Fromme, Torreya **15**: 262. 1915.

Puccinia Maublancii Rangel, Arch. Mus. Nac. Rio de Janeiro **18**: 159. 1916.

Uredo cubangoensis Rangel, Arch. Mus. Nac. Rio de Janeiro **18**: 160. 1916.

Paspalum conjugatum Berg., Rio de Janeiro, Brazil, December 20, 1921, II, *1418*; Gavea, Rio de Janeiro, Brazil, January 13, 1922, II, *1476*.

Paspalum distichum L., Choisica, Peru, July 23, 1920, II, *781*.

Paspalum Hankeanum Presl, Santa Clara, Peru, July 23, 1920, II, iii, *786*.

Paspalum mandiocanum Trin., Lapa, São Paulo, Brazil, March 24, 1922, II, *1677*; Campinas, São Paulo, Brazil, April 2, 1922, II, *1690*.

Paspalum multiflorum Döll., São Paulo, Brazil, January 18, 1922, II, *1478*; Jundiahy, São Paulo, Brazil, alt. 747 meters, March 17, 1922, II, *1642*.

Paspalum paniculatum L., Friburgo, Rio de Janeiro, Brazil, January 6, 1022, II, III, *1464*; same, January 7, 1922, II, *1469*; Villa Augusta, Guarulhos Railway, São Paulo, Brazil, February 25, 1922, II, *1597*; Tremembé, São Paulo, Brazil, March 6, 1922, II, III, *1612*; Arthur Anfim, São Paulo, Brazil, March 15, 1922, II, *1630*; São Joás, São Paulo, Brazil, March 19, 1922, II, III, *1650*; São Roque, São Paulo, Brazil, March 21, 1922, II, III, *1664*; Poá, São Paulo, Brazil, alt. 750 meters, April 14, 1922, II, III, *1731*; Campas do Jordão, São Paulo, Brazil, April 26, 1922, II, III, *1773*; same, alt. 1700 meters, April 28, 1922, II, III, *1781*; same, alt. 1600 meters, April 28, 1922, II, *1793*.

Paspalum plantagineum Nees, Lapa, São Paulo, Brazil, June 3, 1922, II, III, *1937*.

Paspalum plicatulum Michx., Bello Horizonte, Minas Garaes, Brazil, alt. 920 meters, November 21, 1921, II, *1321*; Alto da Serra, São Paulo, Brazil, January 28, 1922, II, iii, *1504*.

Paspalum Regnelli Mez., Juquery, São Paulo, Brazil, February 14, 1922, II, iii, *1554*; Tremembé, São Paulo, Brazil, February 28, 1922, II, iii, 1602; same, March 29, 1922, II, III, *1685*; Jundiahy, São Paulo, Brazil, alt. 747 meters, March 17, 1922, II, *1643*; São Joás, São Paulo, Brazil, March 19, 1922, II, iii, *1651*; São Roque, São Paulo, Brazil, March 21, 1922, II, iii, *1662*; Campinas, São Paulo, Brazil, alt. 700 meters, April 3, 1922, II, *1696*.

Paspalum remotum Remy, Cochabamba, Bolivia, February 26, 1920, II, *336*.

Paspalum virgatum L., Hacienda "Anacuri," Nor Yungas, Bolivia, June 9, 1920, II, *703*; Ypiranga Mus. Bot. Garden, São Paulo, Brazil, March 13, 1922, II, iii, *1628*.

Paspalum sp., Raiz de Serra, Rio de Janeiro, Brazil, alt. 200 meters, November 6, 1921, II, III, *1280*; São Caetano, Brazil, February 22, 1922, *1584*; Campinas, São Paulo, Brazil, alt. 700 meters, April 3, 1922, II, *1697*.

The species is undoubtedly a common one in South America, as it is in southern North America. The species does not possess striking characters by which it can be readily distinguished, and until the alternate host bearing the aecia is discovered, and enough positive observations of the associated stages to determine the range of variability, more or less uncertainty must necessarily attend the determination of individual collections, especially those having only uredinia.

Through the kindness of the authors type material has been examined of *Uredo Eriochloae* Speg., on *Eriochloa annulata*, from Iibcuy, Argentina, *Puccinia Maublancii* Rangel, on *Paspalum densum*, from Rio de Janeiro, Brazil, and *Uredo cubangoensis* Rangel, on *Paspalum mandiocanum*, from Cubango-Niteroy, Brazil, and all three collections show the usual features of *Puccinia substriata*. The specimen distributed as Ule, Myc. Bras. *25*, has also been studied. This seems to be part of the type collection for *Uredo Panici* P. Henn., which was collected by E. Ule, September, 1901, at Juruá-Miry on the river Juruá, now probably within the boundary

of Peru. Although the host is recorded as *Panicum* sp., the leaves, which are about 1.5 cm. wide and 25 cm. long, look far more like *Paspalum* than like *Panicum*. The species has also been collected by Seaver in Trinidad, West Indies, on *Eriochloa punctata*.

This species is most likely to be confused with *Puccinia tubulosa* and *P. levis*, all three occurring on the same group of hosts. In *P. substriata* the urediniospores are moderately large (24–32 μ long), the wall generally cinnamon-brown, the pores 3 or 4, equatorial and usually easily seen, even without heating with lactic acid, while the teliospores are obovate-oblong, with wall slightly or not thickened above.

In *P. tubulosa* the uredinia are often accompanied by hyphoid paraphyses, which are usually inconspicuous, but sometimes are noticeably curved and thickened on one side. The urediniospores may be light cinnamon-brown, but usually are much paler or colorless. The pores are 3 or 4 and equatorial, but usually difficult to see, even by treatment with lactic acid. The teliospores are largely oblong, considerably thickened above, and with the two cells of about the same size and length.

In *P. levis* the urediniospores are about like those of *P. substriata*, but usually with 2 equatorial pores, or sometimes 3, especially on species of *Panicum*. The pores can generally be seen without difficulty. The teliospores are ellipsoid to globoid, with thick, dark walls, thickened somewhat more above, and with the septum often oblique. The pedicels are generally long, and often attached to the spore obliquely.

23. PUCCINIA TUBULOSA (Pat. & Gaill.) Arth. Am. Jour. Bot. **5**: 464. 1918.

Aecidium tubulosum Pat. & Gaill. Bull. Soc. Myc. France **4**: 97. 1888.

Aecidium Uleanum Paz. Hedwigia **31**: 95. 1892.

Uredo paspalicola P. Henn. Hedwigia **44**: 57. 1905.

Puccinia Pilgeriana P. Henn. Bot. Jahrb. **40**: 226. 1908.

Aecidium solaniphilum Speg. An. Mus. Nac. Buenos Aires **23**: 34. 1912.

Uredo duplicata Rangel, Arch. Mus. Nac. Rio de Janeiro **18**: 160. 1916.

Dicaeoma tubulosum Arth. & Fromme, N. Am. Flora 7: 288. 1920.

Solanum subscandens Vell., São Paulo, Brazil, January 23, 1922, O, I, *1495*.

Solanum torvum Sw., Rebeirão Pires, São Paulo, Brazil, March 25, 1922, O, I, *1680*.

Solanum sp., Barbacena, Minas Geraes, Brazil, December 13, 1921, O, I, *1391*; São Joás, São Paulo, Brazil, April 13, 1922, O, I, *1728*; Villa Prudente, São Paulo, Brazil, May 31, 1922, O, I, *1922*.

Panicum maximum Jacq., Rio de Janeiro, Brazil, alt. 700 feet, August 10, 1921, II, *1012*.

Panicum millegrana Poir., Villa Prudente, São Paulo, Brazil, May 31, 1922, II, III, *1924*.

Panicum sciurotis Trin., Reserva Florestal, Itataiya, Rio de Janeiro, Brazil, alt. 1300 meters, May 7, 1922, II, III, *1824*.

Paspalum distichophyllum H. B. K., Arthur Anfim, São Paulo, Brazil, March 15, 1922, II, *1633*, *1640*; Mandaque, São Paulo, Brazil, March 23, 1922, II, *1672*.

Paspalum Humboldtianum Flügge, Hacienda "La Florida," Sur Yungas, Bolivia, May 29, 1920, II, iii, *678*; Hacienda "Anacuri," Nor Yungas, Bolivia, June 4, 1920, II, III, *712*; same, June 5, 1920, II, *719*; Choisica, Peru, July 23, 1920, II, *782*.

Paspalum malacophyllum Trin., Jundiahy, São Paulo, Brazil, alt. 747 meters, March 17, 1922, II, *1645*, *1646*; São Joás, São Paulo, Brazil, alt. 700 meters, April 13, 1922, II, *1725*; Instituto Butantan, São Paulo, Brazil, March 24, 1922, II, iii, *1873*.

Paspalum mandiocanum Trin., Lapa, São Paulo, Brazil, March 24, 1922, II, *1675*.

Paspalum paniculatum L., Hacienda "Anacuri," Nor Yungas, Bolivia, June 5, 1920, II, *726*; Cantareira, São Paulo, Brazil, February 18, 1922, II, III, *1568*; Rebeirão Pires, São Paulo, Brazil, March 23, 1922, II, III, *1679* (growing with the aecia on *Solanum 1680*); Guaruja, Santos, Brazil, July 13, 1922, II, *2010*.

Paspalum pilosum Lam., City Park in Bello Horizonte, Brazil, November 26, 1921, II, *1337*; Guarulhos, São Paulo, Brazil, alt. 700 meters, January 30, 1922, II, *1510*; Taipas, Brazil, June 10, 1922, II, iii, *1948*.

Paspalum plicatulum Michx., São Caetano, São Paulo, Brazil, February 22, 1922, II, *1582*; Lapa, São Paulo, Brazil, March 3, 1922, II, *1607*; Jundiahy, São Paulo, Brazil, alt. 747 meters, March 17, 1922, II, *1647*; São Joás, São Paulo, Brazil, March 19, 1922, II, *1659*.

Paspalum pruinosum Trin., São Paulo, Brazil, January 20, 1922, II, *1482*; Jundiahy, São Paulo, Brazil, March 17, 1922, II, *1644*.

Paspalum Usteri Hack., roadsides, Juquery, São Paulo, Brazil, February 14, 1922, II, *1553*; Jundiahy, São Paulo, Brazil, March 17, 1922, II, *1641*; Lapa, São Paulo, Brazil, March 24, 1922, II, *1676*.

Paspalum sp., Cantareira, São Paulo, Brazil, alt. 737 meters, Feb. 18, 1922, II, III, *1569*; São Joás, São Paulo, Brazil, April 13, 1922, III, *1727* (growing with the aecia on *Solanum 1728*).

Syntherisma digitata (Sw.) Hitchc. (*Panicum horizontale* Meyer), Campinas, São Paulo, Brazil, April 3, 1922, II, *1692*.

Valota saccharata (Buckl.) Chase (*Panicum lachnanthum* Torr.), Cochabamba, Bolivia, February 25, 1920, II, III, *321*; same, March 5, 1920, II, III; *368*.

In two different localities species of rusted *Paspalum* were found growing closely associated with a shrubby *Solanum* bearing an abundance of aecia, giving the appearance of genetic connection. Of *1679* on *Paspalum paniculatum* and *1680* on Solanum Holway wrote from São Paulo, March 30, 1922, that they "were together and no other rusts around." Such records are important in working out the relationships of the grass rusts. Such observations as these were made in Porto Rico by H. E. Thomas, and were followed up in 1917 by careful cultures, the aeciospores from *Solanum torvum* being sown successfully on *Paspalum paniculatum*.

The type material of *Uredo paspalicola* P. Henn. on *Paspalum conjugatum* Berg., from Peru, and of *Puccinia Pilgeriana* P. Henn., on *Paspalum* sp., from Brazil, have been examined by the writer, through the courtesy of the curator of the Berlin Museum. Also the type material of *Uredo duplicata* Rangel, on *Syntherisma sanguinalis* (L.) Dulac (*Panicum sanguinale* L.), II, iii, from Brazil, was kindly sent by the author for study. The portion transmitted was found to possess a few teliospores in addition to the urediniospores, making the identity all the more certain.

The same rust has also been collected by Seaver in Trinidad, on *Syntherisma digitata* (Sw.) Hitchc., II, and on *P. paniculatum* L., II. It is also reported by Mayor (Mém. Soc. Neuch. Sci. Nat. **5**: 578. 1913) on *P. conjugatum*, from Colombia.

24. PUCCINIA LEVIS (Sacc. & Bizz.) Magn. Ber. Deuts. Bot. Ges. **9**: 190. 1891.

Puccinia Paspali Tracy & Earle, Bull. Torrey Club **22**: 174. 1895.
Puccinia goyazensis P. Henn. Hedwigia **34**: 94. 1895.
Diorchidium goyazense Sacc. Syll. Fung. **14**: 359. 1899.
Puccinia Huberi P. Henn. Hedwigia Beibl. **39**: 76. 1900.
Puccinia Puttemansii P. Henn. Hedwigia **41**: 105. 1902.
Dicaeoma leve Arth. & Fromme, N. Am. Flora **7**: 286. 1920.

Axanopus chrysoblepharis (Lag.) Chase, Hacienda "Anacuri," Nor Yungas, Bolivia, June 4, 1920, III, *708*.

Axanopus scoparius Flügge, Hacienda "La Florida," Sur Yungus, Bolivia, May 27, 1920, II, *666*; Villa "Aspiazu," Sur Yungus, Bolivia, June 1, 1920, II, *699*.

Chaetochloa geniculata (Lam.) Millsp. & Chase (*Setaria purpurascens* H. B. K.), Cochabamba, Bolivia, February 28, 1920, II, *348*.

Cymbopogon rufus (Kunth) Rendle, Reserva Florestal, Itatiaya, Brazil, May 14, 1922, II, III, *1852*.

Oplismenus Minarum Nees, Coroico, Nor Yungas, Bolivia, June 14, 1920, II, III, *735*, *736*.

Panicum demissum Trin., Campos do Jordão, São Paulo, Brazil, alt. 1600 meters, April 20, 1922, ii, III, *1737*.

Panicum maximum Jacq., Rio de Janeiro, Brazil, alt. 800 feet, August 13, 1921, II, *1033*.

Panicum millegrana Poir., Tremembé, São Paulo, Brazil, February 18, 1922, II, *1571*; same, February 28, 1922, II, III, *1605*; same, March 6, 1922, II, III, *1615*; Jaragua, peak near Taipas, Brazil, alt. 900 meters, February 19, 1922, II, *1575*; Caetano, São Paulo, Brazil, March 8, 1922, II, *1619*; Prata, São Paulo, Brazil, alt. 825 meters, April 9, 1922, II, *1717*; Reserva Florestal, Itatiaya, Brazil, alt. 600 meters, May 14, 1922, II, III, *1850*; Villa Prudente, São Paulo, Brazil, May 31, 1922, III, *1921*; São Joás, São Paulo, Brazil, July 6, 1922, II, III, *2005*.

Paspalum pilosum Lam., Poá, São Paulo, Brazil, alt. 800 meters, March 11, 1922, II, III, *1624*; São Joás, São Paulo, Brazil, March 19, 1922, II, iii, *1657*; Santa Anna, suburbs of São Paulo, Brazil, May 28, 1922, II, III, *1899*.

Paspalum sp., Huigra, Chimborazo, Ecuador, August 3, 1920, II, *824*; Mandaque, São Paulo, Brazil, March 23, 1922, III, *1669*.

Pennisetum multilatum Hack., Sorata, Bolivia, April 17, 1920, III, *537*.

Tricholaena rosea Nees, Rio de Janeiro, Brazil, alt. 1100 feet, August 13, 1921, II, iii, *1034*; same, alt. 25 feet, September 11, 1921, II, iii, *1102*; Villa Augusta, Guarulhos Railway, São Paulo, Brazil, February 25, 1922, II, *1596*; São Roque, São Paulo, Brazil, March 21, 1922, II, *1663*.

The type collection of *Puccinia goyazensis* P. Henn., III, on *Panicum* sp., and another collection so labeled, showing uredinia only, on *P. cyanescens* Nees, both collected by E. Ule in Brazil, have been examined, and found to be excellent examples of *Puccinia levis*. The collection by Spegazzini, from Asunción, Paraguay (An. Mus. Nac. Buenos Aires **31**: 380. 1922), on *Panicum latifolium* L., also shows a fine development of telia. The type collections of *Puccinia Puttemansii* P. Henn., on *Panicum* sp., and *P. Huberi* P. Henn., on *P. ovalifolium* Poir., both from Brazil, have been studied through the courtesy of the cryptogamic curator of the Berlin Museum. They both show uredinia and telia. The teliospores are more oblong, with fewer oblique pedicels, but conform fairly with most collections of the species.

The species has also been collected in South America by Stevens, at Caracas, Venezuela, on *Paspalum pilosum* Lam., II, and by Thaxter, at Buenos Aires, Argentina, on *Manisuris fasciculata* (Lam.) Hitchc. (*Rottboellia fasciculata* Lam.), II, and also on the latter host by Spegazzini (An. Mus. Nac. Buenos Aires **19**: 319. 1909, listed as *Uredo Rottboellii*), II, Ibicuy, Entre Rios, Argentina. It is possible that *Uredo Rottboellii* Diet. (Bot. Jahrb. **32**: 52. 1902) belongs here, but no material has been studied by the writer. It has also been reported on *Rytilix granularis* (L.) Skeels (*Manisuris granularis* Sw.), from Serra do Mel, Rio Blanco, Brazil, (Ann. Myc. **14**: 67. 1916); on *Paspalum Fournierianum maximum* Thell., Colombia (Mayor, Mém. Soc. Neuch. Sci. Nat. **5**: 471. 1913).

25. PUCCINIA NEGRENSIS P. Henn. Hedwigia **43**: 159. 1904.

Panicum millegrana Poir., Villa Augusta, Guarulhos Railway, São Paulo, Brazil, alt. 750 meters, February 25, 1922, II, III, *1594*.

This Brazilian rust is much like *Puccinia levis*, but with smaller spores. The urediniospores have thin walls, echinulate, with 3 or 4 equatorial pores; the teliospores are more or less globoid, with usually oblique or nearly vertical septa, and uniformly thin walls. The type collection by E. Ule, on *Panicum* sp., has been studied. It came from Moura, on the river Negro, northwestern Brazil, January, 1902.

26. PUCCINIA GRAMINIS Pers. Neues Mag. Bot. **1**: 119. 1794.

Aecidium Berberidis Pers. in J. F. Gmel. Syst. Nat. **2**: 1473. 1791.

Puccinia poculiformis Wettst. Verh. Zool.-Bot. Ges. Wien **35**: 544. 1886.

Puccinia jubata Ellis & Barth. Erythea **4**: 2. 1896.

Puccinia megalopotamica Speg., An. Mus. Nac. Buenos Aires **6**: 224. 1898.

Dicaeoma poculiforme Kuntze, Rev. Gen. 3^3: 466. 1898.

Agrostis verticillata Vill., Cuzco, Peru, June 30, 1920, ii, III, *743*.

Bromus coloratus Steud., Puente Alto near Santiago, Chile, October 3, 1919, II, iii, *83*.

Calamagrostis sp., Temuco, Chile, November 5, 1919, III, *167A*.

Elymus andinus Trin., Recinto, Chile, January 9, 1920, II, *282*; same, III, *283A*.

Hordeum Gussoneanum Parl., Panamavida, Chile, December 14, 1919, II, III, *227*.

Hordeum murinum L., Panamavida, Chile, December 22, 1919, II, III, *246*.

Hordeum vulgare L., Sorata, Bolivia, April 25, 1920, II, III, *569*; Riobamba, Ecuador, August 10, 1920, III, *863*.

Lolium multiflorum Lam., Puente Alto near Santiago, Chile, October 3, 1919, ii, III, *82*.

Poa chilensis Trin., Corral, Chile, November 12, 1919, II, *169*.

Polypogon elongatus H. B. K., Quito, Ecuador, August 20, 1920, II, III, *928*; same, September 2, 1920, II, *958*.

Trisetum spicatum (L.) Richt., Panamavida, Chile, December 10, 1919, II, III, *216*.

Triticum aestivum L. (T. vulgare Vill.), Puerto Varas, Lake Llanguihne, Chile, November 18, 1919, III, *178*.

This is not a long list of hosts for a species that in the northern temperate zone is one most commonly collected, indicating apparently that the species is not so common in South America as it is in North America and Europe. It is also noticeable that no aecia are included in the list, although many species of *Berberis* occur in the regions visited. Apparently no one else has reported the aecia of this species, but other aecia on *Berberis* have a rich development in South America. Spegazzini has pointed out this absence of the aecia of *P. graminis* in his illustrated article on the South American rusts of barberry in the Revista Chilene de Hist. Nat. **25**: 265. 1921.

Through the kindness of Señor Spegazzini I have been able to examine material of *Puccinia megalopotamica* Speg., collected June 2, 1894, near La Plata, Argentina, on *Triticum pubiflorum*. This is the same locality that the type material came from, and presumably the same host. The original publication states that the type was collected in April, 1894, on *Triticum* sp. I can detect no difference between the specimen that I examined and the usual appearance of *P. graminis*.

The species was collected in its uredinial stage on *Agrostis alba* L., at Ambato, Ecuador, by A. Pachano, in 1920. It has also been recorded on "*Agrostis Hackeliana*" (probably a slip of the pen for *Agrostis Hackelii* Fr.), *Avena sativa*, *Bromus pitensis* and *Poa mulalensis*, all from the Botanical Garden at Quito, Ecuador (Bull. Soc. Myc. France **7**: 169. 1891); on *Avena barbata* from Concepción del Uruguay, Argentina (Hedwigia **35**: 228. 1896); on *Triticum sylvaticum* Salisb. (considered a synonym of *Elymus europaeus* L.) from Ensenada, Argentina (An. Mus. Nac. Buenos Aires **6**: 220. 1899); on *Agropyron* sp., *Hordeum halophilum*, and *H. maritimum* from Argentina (An. Mus. Nac. Buenos Aires **19**: 296. 1909); on *Hordeum compressum*, from Colonia Caroya, Córdoba, Argentina (An. Mus. Nac. Buenos Aires **23**: 25. 1912).

27. **Puccinia cacabata** Arthur & Holway sp. nov.

Chloris ciliata Sw., Hacienda "Anacuri," Nor Yungas, Bolivia, June 5, 1920, II, III, *721*.

O and I. Pycnia and aecia unknown.

II. Uredinia amphigenous, scattered, oblong or oblong-linear, 0.5–2 mm. long, early naked, pulverulent, cinnamon-brown, the ruptured epidermis conspicuous; urediniospores broadly ellipsoid or obovoid, 19–23 by 26–29 μ; wall dark cinnamon-brown, 1.5–2 μ thick, evenly echinulate, the pores 3 or rarely 4, equatorial, distinct.

III. Telia amphigenous, scattered, early naked, pulvinate, prominent, oblong or oblong-linear, 0.5–2 mm. long, chocolate-brown, ruptured epidermis conspicuous; teliospores ellipsoid or somewhat obovate, 19–23 by 29–34 μ, rounded or somewhat obtuse above and below, not or slightly constricted at septum; wall dark chestnut-brown, 2.5–3.5 μ thick, usually no thicker above, smooth; pedicel tinted, firm, once to twice length of spore.

In general appearance the host resembles a *Paspalum*, and the rust bears a morphological resemblance to *Puccinia substriata*, which occurs largely on species of *Paspalum*. Beside the type collection, it was also detected on a phanerogamic specimen of *Chloris polydactyla* (L.) Sw., in the grass herbarium of the United States Department of Agriculture, which was collected at Pirapora, Minas Geraes, Brazil, February 8, 1914, by Dorsett & Poponoe *343b*. Both collections show an ample development of the rust.

Through the kindness of Señor Spegazzini I have been able to examine the collection which he made near Ledesma, Argentina, April, 1905, and determined as *P. Chloridis* (An. Mus. Nac. Buenos Aires **19**: 298. 1909), which proves to be the above species. The host is given as *Chloris virgata*, but examination at the U. S. National Herbarium has shown it to be *C. polydactyla* (L.) Sw.

28. PUCCINIA PHRAGMITIS (Schum.) Körn. Hedwigia **15**: 179. 1876.

Aecidium rubellum Pers. in J. F. Gmel. Syst. Nat. **2**: 1473. 1791.
Uredo Phragmitis Schum. Enum. Pl. Saell. **2**: 231. 1803.
Puccinia arundinacea Hedw. f.; Poir. in Lam. Encyc. **8**: 250. 1808.
Dicaeoma rubellum Arth. & Fromme, N. Am. Flora **7**: 322. 1920.

This species was not taken by the Holways. It has been reported from Chile and Argentina, on *Phragmites Phragmites* (L.) Karst. (*P. communis* Trin., *P. occidentalis* Trin., *Arundo Phragmites* L., *A. occidentalis* Sieber). The first report was a collection by Bertero at Valparaiso, Chile, (Montaigne in Gay, Hist. Chile **8**: 45.

1852). It was taken at Santiago, Chile, by Philippi (Winter, Hedwigia **26**: 8. 1887), and at Concepción, Chile, by Neger (Dietel & Neger, Bot. Jahrb. **27**: 4. 1899). Two collections have been reported from Argentina, one by Lorentz & Niederlein at Nueva Roma on the river Sauce (P. Hennings, Hedwigia **35**: 228. 1896), and one by Spegazzini at Ensenada near La Plata (An. Mus. Nac. Buenos Aires **6**: 221. 1899). The rust has also been sent to me from the grass herbarium at the U. S. National Museum, taken at Santiago, Chile, January 15, 1920, by Brother Claude.

29. PUCCINIA PIPTOCHAETII Diet. & Neg. Bot. Jahrb. **27**: 3. 1899.

Piptochaetium ovatum (T. & R.) Desv., Panamavida, Chile, Dec. 13, 1919, II, III, *225*.

Piptochaetium tuberculatum Desv., Sorata, Bolivia, April 19, 1920, III, *547*.

The species has been reported twice before, one collection being by Neger on *Piptochaetium* sp., from Concepción, Chile, on which the name was founded, and another by Spegazzini on *P. tuberculatum*, from La Plata, Argentina, December, 1894, and reported as *Puccinia Stipae* (An. Mus. Nac. Buenos Aires **6**: 225. 1899). A collection on *P. tuberculatum* has also been sent me from the grass herbarium of the U. S. National Museum, made by Ernest Gibson, at Buenos Aires, Argentina, not dated.

30. PUCCINIA SUBANDINA Speg. An. Mus. Nac. Buenos Aires III, **1**: 65. 1902.

This species is only known from the type collection, made by Spegazzini, in 1900, at Carren-leofu, Argentina, on *Poa chorizantha* E. Desv., which I have been permitted to study through the kindness of the collector.

The urediniospores are obovoid or ellipsoid, 20–23 by 31–35 μ; wall cinnamon-brown, 2 μ thick, echinulate, the pores 3, equatorial.

31. PUCCINIA SORGHI Schw. Trans. Am. Phil. Soc. II, **4**: 295. 1832.

Uredo Zeae Desm. Ann. Sci. Nat. II. **13**: 182. 1840; not *U. Zeae* Schw. 1822.

Puccinia Maydis Bér. Atti Sci. Ital. **6**: 475, hyponym. 1845.

Puccinia Zeae Bér. Klotsch Herb. Viv. Suppl. *18*. 1851.
Dicaeoma Sorghi Kuntze, Rev. Gen. 3^2: 470. 1898.

Zea Mays L., Cochabamba, Bolivia, February 26, 1920, III, *338*; Huigra, Prov. Chimborazo, Ecuador, August 4, 1920, III, *837*; Friburgo, Rio de Janeiro, Brazil, January 7, 1922, II, *1467*.

Collections of this rust have been made at Guarapi, Paraguay, by Balansa, in 1882 (Spegazzini, An. Soc. Ci. Arg. **17**: 91, 125. 1884), at Boco de la Riachnelo, Argentina, by Spegazzini, in 1880 (An. Soc. Ci. Arg. **10**: 8. 1880), at Tremembé, São Paulo, Brazil, by Puttemans, in 1901 (Hennings, Hedwigia **41**: 296. 1902), at Morro de Chapeo and Campinas, São Paulo, Brazil, by Noack, in 1896–8 (Sydow, Ann. Myc. **5**: 355. 1907), and at Yarumito, alt. 1340 meters, and Angelopolis, alt. 1600 meters, Colombia, by Mayer, in 1910 (Mém. Soc. Neuch. Sci. Nat. **5**: 472. 1913). All these records have been made under the unestablished name, *Puccinia Maydis*. It was also reported under the name *P. Sorghi* from the island of São Francisco, Brazil, taken by Ule in 1885 (Pazschke, Hedwigia **31**: 96. 1892), and from St. Catharina, Brazil, taken by Lorentz, in 1872 (Hennings, Hedwigia **35**: 244. 1896).

32. **Puccinia variospora** Arthur & Holway sp. nov.

Andropogon hirtiflorus (Nees) Kunth, Hacienda "Anacurí," Nor Yungas, Bolivia, June 4, 1920, II, *713*; Quito, Ecuador, August 13, 1920, II, *876*.

Andropogon saccharoides Sw., Hacienda "Anacuri," Nor Yungas, Bolivia, June 4, 1920, II, III, *709* (type).

O and I. Pycnia and aecia unknown.

II. Uredinia hypophyllous, scattered, elongate-oblong or linear, 0.1–0.3 mm. broad by 0.5–5.5 mm. long, early naked, reddish or light cinnamon-brown, somewhat pulverulent, ruptured epidermis not distinct; urediniospores globoid, 20–27 μ in diameter; wall cinnamon-brown or colorless, moderately thick, 2–3 μ, evenly and prominently echinulate, the pores 6–8, scattered, usually distinct when walls are colored.

III. Telia hypophyllous, scattered, oblong or linear, 0.5–4 mm. long, early naked, chestnut-brown, at first pulvinate, becoming pulverulent, ruptured epidermis inconspicuous; teliospores broadly ellipsoid or oblong, 23–26 by 30–35 μ, rounded above and below, slightly or not constricted at septum; wall smooth, light chestnut-

brown, 2–4 μ thick, slightly thicker above, 3–7 μ; pedicel nearly or quite colorless, slender, once length of spore.

It is possible that the collection made by F. W. Neger (Dietel & Neger, Bot. Jahrb. **27**: 3. 1899) near Concepción, Chile, on *Andropogon hirtiflorus*, showing only uredinia, may belong here, but the writer has had no opportunity to examine it. It was tentatively referred to *P. Andropogonis*, where it probably does not belong.

33. PUCCINIA AEGOPOGONIS Arth. & Holw.; Arth. Am. Jour. Bot. **5**: 467. 1918.

Dicaeoma Aegopogonis Arth. & Fr. N. Am. Flora **7**: 285. 1920.

Aegopogon cenchroides Humb. & Bonpl., Sorata, Bolivia, April 16, 1920, II, iii, 535; Quito, Ecuador, August 18, 1920, II, III, *914*.

There appears to be no record of this species having been taken in South America before.

34. PUCCINIA POLYPOGONIS Speg. An. Mus. Nac. Buenos Aires **19**: 300. 1909.

Uredo Polypogonis Speg. An. Mus. Nac. Buenos Aires **6**: 240. 1899.

Polypogon elongatus H. B. K., Therezopolis, Brazil, September 28, 1921, II, *1155*; Barbacena, Minas Garaes, alt. 1178 meters, December 13, 1921, II, *1392*; Campos do Jordão, Brazil, May 1, 1922, II, *1797*.

This species has been recorded three times by Spegazzini, but not on the above host. It was taken first on *Polypogon monspeliensis* Desf., January, 1881, in Tuyu, Argentina, and reported in An. Soc. Ci. Arg. **12**: 75 (1881), under the name *Uredo rubigo-vera*. It was also collected in several places in Argentina, Patagonia and Uruguay between 1885 and 1896, on both *P. monspeliensis* and *P. interruptus* H. B. K., these collections being made the basis of the new species, *Uredo Polypogonis* (*l. c.*). The third record is for the type of *Puccinia Polypogonis*, which the writer has examined through the kindness of Señor Spegazzini. It was collected on *P. monspeliensis*, at Lake Muster in Patagonia, December, 1902. The urediniospores have pale walls, with 6–8 readily demonstrated pores.

On October 13, 1921, Holway wrote from Therezopolis that "there is a possibility that no. 1180 on Verbena and no. 1155 are

connected. I have found them together in the greatest abundance in several places." This is *Aecidium Verbenae* Speg., whose alternate form has not yet been established. The evidence in the present instance is much too slight to give it more weight than a suggestion.

35. PUCCINIA MOYANOI Speg. An. Mus. Nac. Buenos Aires **19**: 299. 1909.

This species was not taken by the Holways. Only the original collection is known, which was loaned to the writer by Señor Spegazzini. It was collected on Lake San Martin, in southern Argentina, February, 1903, on *Agrostis Moyanoi* Speg., and shows both uredinia and telia. It is similar in its characters to *Puccinia Polypogonis*, but the urediniospores have 8–10 pores, readily demonstrated with lactic acid, are somewhat thicker walled, and there is an abundance of mesospores in the telia.

36. PUCCINIA VEXANS Farl. Proc. Am. Acad. **18**: 32. 1883.
Puccinia aristidicola P. Henn. Hedwigia **35**: 243. 1896.
Dicaeoma vexans Kuntze, Rev. Gen. 3^3: 471. 1898.

Bouteloua curtipendula (Michx.) Torr., Cochabamba, Bolivia, March 6, 1920, II, x, III, *372½*.

The only other record for this common North American rust, with its remarkable amphispores, is the collection by Galander, which the writer has examined, made at Córdoba, Argentina, in March, 1881, and under the impression that the grass was an *Aristida*, was described as a new species (*l. c.*) by Hennings. Only the usual urediniospores and teliospores and no amphispores are present on the Córdoba specimen, and only a few amphispores on the Holway collection.

37. PUCCINIA FLACCIDA Berk. & Br. Jour. Linn. Soc. **14**: 91. 1873.
Puccinia abnormis P. Henn. Hedwigia **35**: 243. 1896.
Puccinia subdiorchidioides P. Henn. Hedwigia **35**: 244. 1896.
Dicaeoma flaccidum Kuntze, Rev. Gen. 3^3: 468. 1898.

Eriochloa Crus-galli (L.) Beauv. (*Panicum Crus-galli* L.), Cochabamba, Bolivia, February 25, 1920, II, iii, *323*; same, March 14, 1920, II, III, *412*; Santa Clara, Peru, July 23, 1920, II, *785*.

Panicum millegrana Poir., Reserva Florestal, Itatiaya, Brazil, May 9, 1922, II, III, *1834*.

The writer has examined the collections on which the two names by Hennings were based. The first was collected on the river Tercero, province of Córdoba, Argentina, by Galander, March, 1882, and the other on the river Lujan, Buenos Aires, Argentina, by Bettfreund, April 1883. It was also collected by Spegazzini in Tucumán, Argentina, April, 1906 (An. Mus. Nac. Buenos Aires **19**: 297. 1909). All three of these collections were on *Eriochloa Crus-galli*.

38. PUCCINIA HIBISCIATA (Schw.) Kellerm. Jour. Myc. **9**: 110. 1903.

Caeoma (Aecidium) hibisciatum Schw. Trans. Am. Phil. Soc. II. **4**: 293. 1832.

Aecidium Malvastri Ellis & Tracy, Jour. Myc. **7**: 43. 1891.

Puccinia Muhlenbergiae Arth. & Holway, Bull. Lab. Nat. Hist. Univ. Iowa **5**: 317. 1902.

Puccinia subglobosa Speg. An. Mus. Nac. Buenos Aires **19**: 300. 1909. Not *P. subglobosa* Diet. & Holway, 1901.

Puccinia Spegazziniella Sacc. & Trav.; Sacc. Syll. Fung. **20**: 627. 1911.

The only known South American collection of this very common rust of North America was taken by Spegazzini on *Sporobolus asperifolius* (Nees & Meyen) Thurber, at Mendoza, Argentina, January, 1908, and described and figured as a new species (*l. c.*). It was kindly loaned by the collector for study. The rust is abundant in North America, not only on more than one genus of grasses, but also on many species of *Malvaceae*, which bear the aecia. The aecia are small and nearly or quite colorless, and are readily distinguished from the large aecia belonging to *Puccinia interveniens*.

39. PUCCINIA TRICHLORIDIS Speg. An. Mus. Nac. Buenos Aires **19**: 298. 1909.

This species is only known from the three collections made in Argentina, 1904–6, by Spegazzini. They are all on *Trichloris mendocina* (Phil.) Kurtz, and from near Perico, Salta, about La Rioja and Mendoza. The first of these was kindly loaned by the

collector. In its morphological characters it much resembles *P. Polypogonis* Speg. The urediniospores have many scattered pores, not easily counted.

40. **Puccinia tornata** Arthur & Holway sp. nov.

Hordeum andinum Trin., La Paz, Bolivia, March 27, 1920, II, III, *474* (type); same, April 4, 1920, II, III, *495*; same, April 6, 1920, II, *498*; same, May 16, 1920, II, III, *608*, *609*.

O and I. Pycnia and aecia unknown.

II. Uredinia hypophyllous, rarely epiphyllous, scattered without marked discoloration, oval or oblong, 0.2–0.8 mm. long, somewhat tardily naked by a longitudinal slit of the epidermis, moderately

Fig. 2. Teliospores of *Puccinia tornata* on *Hordeum* (collection *474*). × 500.

pulverulent, pale cinnamon-brown or yellowish, the ruptured epidermis conspicuous; urediniospores broadly ellipsoid or globoid, 20–23 by 23–26 μ in the smaller sori, 21–26 by 23–30 μ in the larger sori; wall nearly or quite colorless 1–1.5 μ thick, finely and closely verrucosely-echinulate, the pores scattered, 6–8, usually indistinct.

III. Telia amphigenous, irregularly scattered, ellipsoid or oblong, 0.1–0.5 mm. broad by 0.2–1.3 mm. long, prominent, tardily naked by longitudinal slitting of the epidermis, blackish-brown, pulverulent, ruptured epidermis conspicuous; teliospores regularly ellipsoid, 16–22 by 26–40 μ, rounded, obtuse, or narrowed above and below, slightly or not constricted at septum; wall chestnut-brown, 1–2 μ thick, usually no thicker above, smooth; pedicel once length of spore, slender, slightly tinted.

The teliospores of this species are well represented by the illustration (fig. 2), taken from type material, no. *474*.

41. PUCCINIA ATRA Diet. & Holw.; Holway, Bot. Gaz. **24**: 29. 1897.

Puccinia eslavensis Dietel & Holway; Holway, Bot. Gaz. **24**: 29. 1897.

Dicaeoma atrum Arth. Résult. Sci. Congr. Bot. Vienne 344. 1906.

Pennisetum chilense (Desv.) Jackson, La Paz, Bolivia, March 20, 1920, II, *438*; same, May 14, 1920, II, *605*.

Panicum Rudgii R. & S., Sylvestre, Rio de Janeiro, Brazil, alt. 500 feet, September 16, 1921, II, *1116*.

Paspalum prostratum Scrib. & Merr., Sorato, Bolivia, April 12, 1920, II, III, *507*.

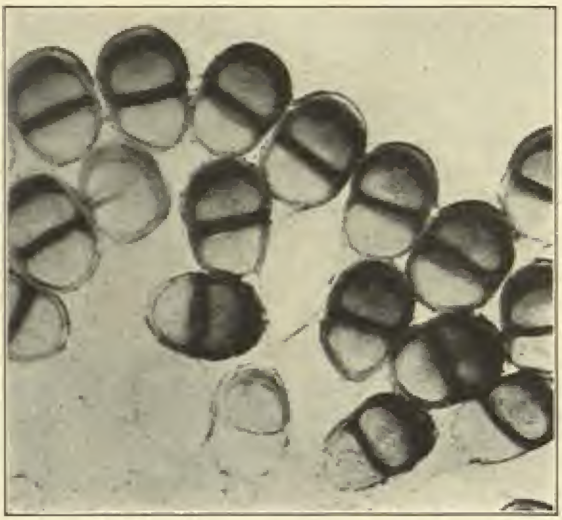

FIG. 3. Teliospores of *Puccinia atra* on *Paspalum* (collection *507*). × 500.

Valota insularis (L.) Chase (*Panicum leucophaeum* H. B. K.), Taquara, Rio de Janeiro, Brazil, August 30, 1921, II, III, *1082*; Rio de Janeiro, Brazil, alt. 600 feet, September 24, 1921, II, iii, *1152*; Petropolis, alt. 700 feet, November 9, 1921, II, III, *1290*; Prata, Brazil, April 7, 1922, II, *1704*.

This species of rust has not before been reported from South America. It has urediniospores with finely verrucose walls, 2–3.5 μ thick, and 4–6 equatorial pores.

The characteristic teliospores are well shown by the illustration (fig. 3), taken from material of no. *507*.

42. PUCCINIA SUBNITENS Dietel, Erythea 3: 81. 1895.

Aecidium Sarcobati Peck, Bot. Gaz. 6: 240. 1881.
Puccinia Aristidae Tracy, Jour. Myc. 7: 281. 1893.
Puccinia thalassica Speg. An. Mus. Nac. Buenos Aires 6: 225. 1899.
Dicaeoma Sarcobati Arth. Résult. Sci. Congr. Bot. Vienne 344. 1906.
Puccinia Sarcobati Bethel; Barth. N. Am. Ured. *2464*. 1921.

Aristida Adscensionis L., Arequipo, Peru, July 10, 1920, II, III, *770*, *771*.

Aristida enodis Hack., La Paz, Bolivia, March 31, 1920, II, *489*.

Distichlis spicata (L.) Greene, Pechilema, Chile, October 11, 1919, II, *106*; Baños de Cauquenes, Rancagua, Chile, January 13, 1920, III, *294*; Cochabamba, Bolivia, March 16, 1920, II, *413*.

All the collections here listed as well as others examined from South America, have somewhat smaller urediniospores and teliospores with thinner walls than most of those from North America, but no other differences are discernible. The sori on *Aristida* do not differ from those on *Distichlis*, and the general habit and texture of the two hosts are the same, although their inflorescence is very unlike.

The species has been recorded from Chile by Neger (Dietel & Neger, Bot. Jahrb. 24: 155. 1897) from Concepción, and by Spegazzini (Fungi Chilenses 22. 1910) from Batuco, on *Distichlis thalassica*. It is also known as *P. thalassica* Speg. (*l. c.*), based on a collection from La Plata, Argentina, made in 1893. The original packet, most courteously loaned by Señor Spegazzini, gives the host name as *Distichlis thalassica* in Spegazzini's handwriting, but in the publication it was changed to *D. scoparia*. This original material has been examined at the grass herbarium of the U. S. National Museum and pronounced to be *D. thalassica* and not *D. scoparia*.

Other collections from South America have been found by Mrs. Agnes Chase, to whom I am indebted for many courtesies, among the grass collections at the U. S. National Museum, and are now in the Arthur Herbarium at Lafayette, Indiana:

D. scoparia (Kunth) Arech., General Roco, Valley of Rio Negro, Argentina, alt. 250–360 meters, 1914, Fischer *96*; Villa del Rosario, Dept. Rio Secundo, Argentina, 1902, Stuckert *61*.

D. spicata (L.) Greene, El Volcán, Prov. Jujuy, Argentina, alt. 2000 meters, Lillo *5265*.

D. thalassica (H. B. K.) Desv., Pacasmayo, Peru, 1914, Rose *18518*.

D. viridis Phil., Capiapo, Chile, 1888, Philippi.

It is interesting to note that no aecial collections from South America have come to hand that can be assigned to this species, although in North America almost one hundred aecial hosts are known belonging to twenty four families. Holway records that a special search revealed no traces of aecia at the two Chilean localities for his numbers 106 and 294.

43. PUCCINIA CYNODONTIS Lacroix, in Desmaz. Pl. Crypt. II. *655*. 1859.

Aecidium Plantaginis Ces. Erb. Critt. Ital. *247*. 1859.

Capriola dactylon (L.) Kuntze (*Cynodon dactylon* Pers.), Rio de Janeiro, Brazil, roadsides little above sea level, September 11, 1921, II, III, *1103*; Petropolis, Brazil, alt. 700 meters, November 3, 1921, II, iii, *1273*.

This is probably the first record for South America. The rust is common on this grass in many parts of the world. In North America it produces telia sparingly, and chiefly in the southernmost part of its range. The aecia, which occur on species of *Plantago*, have not yet been found in any part of America.

44. **Puccinia Opuntiae** (Magn.) Arthur & Holway, comb. nov.

Aecidium Opuntiae Magn. Ber. Deut. Bot. Ges. **16**: 151. 1898.

Opuntia sulphurea Don, Cochabamba, Bolivia, March 1, 1920, O, I, *357*.

Bouteloua simplex Lag., Cochabamba, Bolivia, March 2, 1920, ii, III, *359*.

O. Pycnia subepidermal, globoid; ostiolar filaments extruded.

I. Aecia caulicolous, subcortical, in large groups, usually about the areolae, cylindric 0.3–0.4 mm. in diameter, 0.5–0.8 mm. high; peridium whitish, firm, the margin erose; peridial cells in face view

polygonal, in side view squarish, abutted with overlapping edge, 30–35 µ broad by 15–23 µ long, the outer wall exceedingly thick, 16–20 µ, transversely striate, smooth, the inner wall 3–4 µ thick, prominently verrucose; aeciospores irregularly oblong, elliptic or globoid, 13–18 by 18–26 µ; wall colorless, 1–1.5 µ thick, closely and finely verrucose.

II. Uredinia not seen; urediniospores globoid or broadly ellipsoid, 16–23 by 19–26 µ; wall light cinnamon-brown or golden, thin, 1–2 µ, closely and finely verrucose, the pores 6–8, scattered, moderately distinct.

III. Telia hypophyllous, oblong or linear, 0.5–4 mm. long, early naked, pulvinate, prominent, blackish-brown, ruptured epidermis not apparent; teliospores broadly ellipsoid, 20–26 by 32–38 µ, rounded at both ends, or somewhat narrowed below, not constricted at septum; wall dark chestnut-brown, 1.5–2.5 µ thick, noticeably thicker above, 3–7 µ; pedicel pale-yellow or colorless, once to twice length of spore; mesospores very numerous, often more than 80 per cent.

The original collection for *Aecidium Opuntiae* was made by O. Kuntze, at Cochabamba, Bolivia, the end of March, 1892, on an undetermined species of *Opuntia*. The collection made by the Holways in the same region agrees well with the elaborate description and illustration by Magnus (*l. c.* pl. 8). The aecia apparently for the most part surround the spines in large spreading groups.

Two other collections are recorded for aecia on *Cactaceae*, which have not been seen by the writer. One on *Opuntia digitalis*, collected by Bruch, February, 1908, in Sierra de Anfama, Argentina, may be the same, according to Spegazzini (An. Mus. Nac. Buenos Aires **19**: 321. 1909), but the description is too meager to venture an opinion. Another on *Cereus* sp., collected by Hieronymus, November 11, 1881, between Pan de Azuacar and Colanchanga, Córdoba, Argentina, given the name *Aecidium Cerei* by Hennings (Hedwigia **35**: 258. 1896) is clearly distinct.

In a letter to the writer dated February 9, 1921, Professor Holway says: "As to the *Aecidium* on *Opuntia*, the *Bouteloa* rust and this *Aecidium* were together on one mountain side, and although both hosts were everywhere there was not a trace of the rust anywhere else." The species is a very striking and distinctive one.

45. PUCCINIA SETARIAE Diet. & Holw.; Holway, Bot. Gaz. **24**: 28. 1897.

Dicaeoma Setariae Arth. Résult. Sci. Congr. Bot. Vienne 344. 1906.

Chaetochloa geniculata (Lam.) Millsp. & Chase, Baños de Cauquenes, Chile, January 13, 1920, II, *290*; La Falda, Córdoba, Argentina, August 14, 1922, II, iii, *2028*.

This name has been used but once for a South American rust. It was assigned by Spegazzini to a collection made by him near Concepción, Chile, on *Setaria caudata* R. & S. (Fungi Chilensis 22. 1910), which the writer has not seen, but the description would indicate that it is not this species. Single collections of rusts on *Chaetochloa* (*Setaria*) are often difficult to place, with the information and observations usually available.

46. PUCCINIA LEPTOCHLOAE Arth. & Fromme, Torreya **15**: 263. 1915.

Dicaeoma Leptochloae Arth. & Fromme, N. Am. Flora **7**: 321. 1920.
Puccinia subtilipes Speg. An. Mus. Nac. Hist. Nat. Buenos Aires **31**: 386. 1922.

This species was obtained by Dr. Spegazzini at Asunción, Paraguay, in July, 1919, on *Leptochloa virgata* (L.) Beauv. No specimen has been seen by the writer. In North America it occurs on *L. filiformis* in southern United States, Mexico and the West Indies.

47. **Puccinia melicina** Arthur & Holway sp. nov.

Melica scabra H. B. K., Cochabamba, Bolivia, March 8, 1920, II, III, *384*; La Paz, Bolivia, March 24, 1920, II, III, *457*; same, May 12, 1920, II, III, *598* (type); Cuzco, Peru, June 30, 1920, III, *746*.

O. and I. Pycnia and aecia unknown.

II. Uredinia hypophyllous, scattered, oval or oblong, 0.3–0.8 mm. long, early naked, cinnamon-brown, pulverulent, ruptured epidermis evident; urediniospores globose or globoid, 19–26 μ in diameter; wall cinnamon-brown, moderately thick, 1.5–2.5 μ, closely and finely verrucose, the pores 6–8, scattered, moderately distinct.

III. Telia hypophyllous, scattered, oval or oblong, 0.3–1 mm. long, sometimes longer, early naked, dark chestnut-brown, pulvinate, prominent, ruptured epidermis inconspicuous; teliospores broadly ellipsoid, 21–26 by 29–35 μ, rounded or somewhat obtuse above and below, slightly or not constricted at septum; wall smooth, dark chestnut-brown, 1.5–3 μ thick, thicker above, 3–7 μ; pedicel colorless, once length of spore, often placed obliquely.

The character of the teliospores is well shown in the illustration (fig. 4), taken from material of no. *746*.

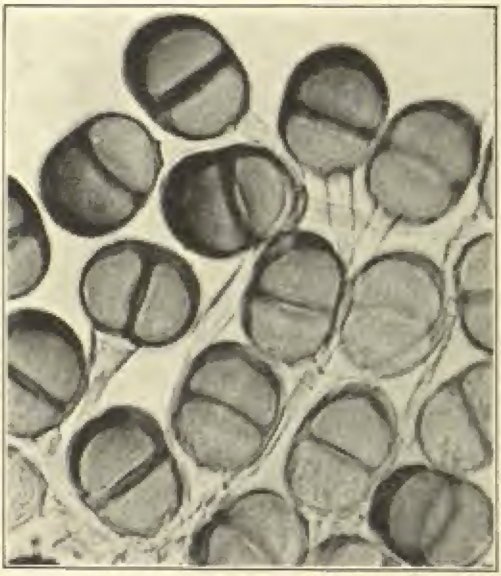

FIG. 4. Teliospores of *Puccinia melicina* on *Melica* (collection *746*). Note the obliquely placed pedicels. × 500.

48. PUCCINIA VIRGATA Ellis & Ev. Proc. Acad. Phila. **1893**: 154. 1893.

Caeoma Andropogi Schw. Trans. Am. Phil. Soc. II. **4**: 290. 1832. Not *Puccinia Andropogi* Schw. 1832.

Dicaeoma virgatum Kuntze, Rev. Gen. 3^{3}: 471. 1898.

Sorghastrum nutans (L.) Nash (*Andropogon nutans* L.), Therezopolis, Brazil, October 11, 1921, II, *1208*; São Paulo, Brazil, January 23, 1922, II, III, *1499*; Tremembé, Brazil, January 24, 1922, II, *1499a*; São Joás, Brazil, March 19, 1922, II, III, *1658*.

The species is here first reported for South America.

49. PUCCINIA KAERNBACHII (P. Henn.) Arth. Bull. Torrey Club **46**: 110. 1919.

Uredo Kaernbachii P. Henn. Bot. Jahrb. 18: Beibl. **44**: 23. 1894.
Puccinia Nakanishikii Dietel, Bot. Jahrb. **34**: 585. 1904.
Puccinia andropogonicola Speg. An. Mus. Nac. Buenos Aires **19**: 299. 1909.
Uredo andropogonicola Speg. An. Mus. Nac. Buenos Aires **19**: 315. 1909.
Puccinia posadensis Sacc. & Trott. in Sacc. Syll. Fung. **21**: 691. 1912.
Puccinia venustula Arth. Mycologia **10**: 128. 1918.
Dicaeoma Kaernbachii Arth. & Fr., N. Am. Flora **7**: 283. 1920.

Andropogon brevifolius Sw., Huigra, Ecuador, August 5, 1920, III, *847*.

Andropogon condensatus H. B. K., Hacienda "La Florida," Prov. Sur Yungas, Bolivia, May 29, 1920, II, *679*; Therezopolis, Brazil, October 11, 1921, *1208*, *1209*; Barbacena, Minas Garaes, alt. 3400 feet, December 14, 1921, II, *1399*; Nova Friburgo, Rio de Janeiro, January 1, 1922, II, *1439*; São Joás, São Paulo, March 19, 1922, II, III, *1660*.

Andropogon sp., Rio de Janeiro, Brazil, alt. 800 feet, December 20, 1921, II, *1417*; Juquery, São Paulo, Brazil, February 14, 1922, II, *1552*; La Falda, Argentina August 24, 1922, II, *2046*.

Cymbopogon bracteatus (Willd.) Hitchc. & Chase, Mandaque, São Paulo, Brazil, March 23, 1922, II, *1671*.

Erianthus angustifolius Nees, Arthur Anfim, São Paulo, Brazil, March 15, 1922, II, III, *1629*; Taipas, Brazil, June 10, 1922, II, III, *1954*.

Erianthus asper Nees, Therezopolis, Brazil, October 8, 1921, II, *1200*.

Erianthus Trinii Hack., Tremembé, São Paulo, Brazil, February 28, 1922, II, *1603*.

Imperata brasiliensis Trin., Petropolis, Brazil, alt. 700 meters, October 30, 1921, II, *1258*.

Imperata contracta (H. B. K.) Hitchc., Therezopolis, Brazil, alt. 1000 meters, October 11, 1921, II, III, *1213*.

This species has dark colored urediniospores with equally dark and conspicuous paraphyses. It occurs in nearly all the warmer regions of the world.

Through the kindness of Señor Spegazzini I have been able to examine two of his collections, on which two of the above synonyms are founded. *Puccinia andropogonicola* was found at Posados, Misiones, Argentina, January, 1901, on *Andropogon condensatus*, and *Uredo andropogonicola* on the same host, near Tucumán, Argentina, April 10, 1906.

50. PUCCINIA PURPUREA Cooke, Grevillea **3**: 15. 1876.

Dicaeoma purpureum Kuntze, Rev. Gen. 3^3: 470. 1898.
Puccinia Sorghi-halepensis Speg. An. Mus. Nac. Buenos Aires **31**: 386. 1922.

Holcus halepensis L. (*Sorghum halepense* Pers.), Lima, Peru, July 21, 1920, II, iii, *775*; Santa Clara, Peru, July 23, 1920, II, *788*; Prassaguera near Santos, São Paulo, Brazil, Feb. 9, 1922, II, III, *1545*; São Paulo, Brazil, May 24, 1922, II, *1874*.

Holcus Sorghum L. (*Sorghum vulgare* Pers.), Rio de Janeiro, Brazil, August 11, 1921, II, III, *1019*.

There are three South American records for this common rust on cultivated sorghums: Seringal Auristella, on the Rio Acre, northeast Peru, 1911, Ule *3516* (Sydow, Ann. Myc. **14**: 67. 1916); Trinidad, British West Indies, Rorer (Arthur, Bot. Gaz. **73**: 66. 1922); and Paraguay (Spegazzini, *l. c.*).

51. PUCCINIA GYMNOTRICHIS P. Henn. Hedwigia **35**: 242. 1896.

Puccinia Burmeisteri Speg. An. Mus. Nac. Buenos Aires **6**: 222. 1899.
Puccinia Arthuri Sydow, Monog. Ured. **1**: 775. 1904.
Dicaeoma Arthuri Arth. & Fromme, N. Am. Flora **7**: 293. 1920.

Pappophorum vaginatum Buckl., Cochabamba, Bolivia, March 4, 1920, ii, III, *367*.

Pennisetum latifolium Spreng. (*Gymnothrix latifolia* Schult.), Tremembé, São Paulo, Brazil, March 6, 1922, II, III, *1610*; same, May 30, 1922, II, III, *1904*; São Joás, São Paulo, Brazil, alt. 700

meters, April 13, 1922, II, III, *1726*; Pirahy, Parana, Brazil, June 19, 1922, II, III, *1972*.

Pennisetum Preslii (Kunth) Trin. (*Gymnothrix Preslii* Kunth), Sorata, Bolivia, April 11, 1920, II, *503*.

Pennisetum setosum Sw., Villa Aspiazu, Sur Yungas, Bolivia, May 31, 1920, II, *687*; Hacienda "Anacuri," Nor Yungas, Bolivia, June 4, 1920, II, *714*.

Pennisetum tristachyum (H. B. K.) Steud. (*Gymnothrix tristachya* H. B. K.), Quito, Ecuador, August 25, 1920, II, *945*.

Pennisetum sp., Campos do Jordão, São Paulo, Brazil, April 30, 1922, II, III, *1795*.

I have been accorded the privilege of studying the type collection of *P. Gymnotrichis*, now in the Berlin Museum, which was taken on *G. latifolia*, in Sierra de Tucumán, Argentina, March, 1872, by Lorentz, and also the type of *P. Burmeisteri*, now in the herbarium of Señor Spegazzini, which was taken on *Pennisetum tristachyum*, at Ensenada near La Plata, Argentina, April 13, 1889. The species was also collected on the last named host by G. von Lagerheim, at Quito, Ecuador, January, 1891.

52. **Puccinia decolorata** Arthur & Holway sp. nov.

Bromus coloratus Steud., La Paz, Bolivia, March 24, 1920, II, III, *456*.

O and I. Pycnia and aecia unknown.

II. Uredinia hypophyllous, scattered, oval, small, 0.1–0.3 mm. long, early naked, yellowish, pulverulent, ruptured epidermis inconspicuous; paraphyses numerous, strongly capitate, 16–20 by 35–45 μ, colorless, the wall smooth, usually thin, 1–3 μ thick; urediniospores globoid or broadly ellipsoid, 21–23 by 21–26 μ; wall pale yellow, thin, 1 μ, finely and closely echinulate, the pores 6, scattered, moderately distinct.

III. Telia hypophyllous, scattered, intercostal, oval, small, 0.1–0.3 mm. long, early naked, chestnut-brown, somewhat pulverulent, ruptured epidermis inconspicuous; teliospores ellipsoid or obovoid, 19–23 by 29–32 μ, rounded or obtuse above and below, slightly constricted at septum; wall smooth, chestnut-brown, 2–3 μ thick, thicker above, 4–7 μ; pedicel tinted, once length of spore or less.

This species closely resembles *Puccinia melicina* Arth. & Holw. in its general morphological characters, but differs especially in the color and markings of the urediniospores, presence of paraphyses, and absence of oblique teliospores.

53. **Puccinia Nasellae** Arthur & Holway sp. nov.

Nasella caespitosa Griseb., Cochabamba, Bolivia, March 11, 1920, II, III, *398*; La Paz, Bolivia, March 24, 1920, II, *461*; same, May 12, 1920, II, III, *600*; Sorato, Bolivia, April 12, 1920, II, III, *508* (type).

Nasella chilensis (Trin.) Desv., Viña del Mar, Chile, September 6, 1919, III, *12*; La Paz, Bolivia, March 18, 1920, II, *418*.

Nasella flaccidula Hack., La Paz, Bolivia, April 6, 1920, II, III, *497*.

Nasella pubiflora (T. & R.) Desv., Cuzco, Peru, June 20, 1920, ii, III, *744*.

Nasella sp., La Falda, Córdoba, Argentina August 14, 1922, II, III, *2026a*; same, August 24, 1922, II, iii, *2047*.

Stipa brachyphylla Hitchc., La Paz, Bolivia, March 20, 1920, II, iii, *433*.

O and I. Pycnia and aecia unknown.

II. Uredinia hypophyllous, intercostal, ellipsoid or oblong, small, 0.2–0.5 mm. long, early naked, usually pulvinate, somewhat pulverulent, cinnamon-brown, ruptured epidermis inconspicuous; paraphyses usually very numerous, irregularly bent or curved, gradually enlarged above, the wall colored, pale to dark cinnamon-brown, thick, 1–3 µ below gradually increasing to 3–5 µ above, smooth; urediniospores globoid or ellipsoid, 20–26 by 20–30 µ; wall cinnamon-brown, about 2 µ thick, verrucose-echinulate, the pores 6–8, usually distinct, scattered.

III. Telia hypophyllous, rarely amphigenous, ellipsoid or oblong, small, 0.2–0.7 mm. long, early naked, pulvinate, prominent, cinnamon- to blackish-brown, ruptured epidermis inconspicuous; paraphyses often as abundant as with the uredinia; teliospores ellipsoid or ellipsoid-obovate, 16–20 by 30–38 µ, rounded or obtuse above, rounded or somewhat narrowed below, slightly constricted at septum; wall chestnut-brown, about 2 µ thick, much thicker above, 5–12 µ, smooth; pedicel slender, persistent, once to twice length of spore, colored.

Although the collection made at Sorato, which is taken as the type, was found growing with an abundant development of small, pale aecia on a species of *Desmodium* no. *526* (erroneously labeled *Phaseolus*), the evidence of genetic connection was not strong enough

FIG. 5. Teliospores and paraphyses of *Puccinia Nasellae* on *Nasella* (collection *12*). × 500.

to warrant its inclusion. Holway said, however (in letter of September 28, 1921), that "This is never followed by any other form" on the same host. It is *Aecidium Desmodii* P. Henn. Hedwigia **35**: 259 (1896), which was made a synonym of *Uromyces Hedysari-paniculati* (Schw.) Farl. in the N. Am. Flora **7**: 248 (1912), but doubtless erroneously so.

The abundant development of paraphyses together with the somewhat smaller urediniospores and much smaller teliospores in this species (Fig. 5) distinguishes this species from the one following. Although all collections but one so far identified have been on species of *Nasella* there is every reason to believe that the same rust occurs on various species of *Stipa* also.

54. **Puccinia digna** Arthur & Holway sp. nov.

Aecidium graminellum Neesianum Speg. An. Mus. Nac. Buenos Aires **6**: 233. 1899.

Puccinia graminella Neesiana Sydow, Monog. Ured. **1**: 815. 1904.

Nasella chilensis (Trin.) Desv., Papudo, Chile, September 18, 1919, ii, III, *39*.

Nasella pubiflora (T. & R.) Desv.; La Paz, Bolivia, March 24, 1920, ii, III, *449*; same, March 28, 1920, II, III, *479*.

Stipa ibarrensis H. B. K., Quito, Ecuador, August 16, 1920, II, III, *907*.

Stipa Ichu (R. & P.) Kunth, Cochabamba, Bolivia, February 26, 1920, ii, III, *330*; same, February 28, 1920, III, *342*; same, II, III, *345*; same, March 3, 1920, III, *362*; same, March 10, 1920, II, III, *387*, *389*; La Paz, Bolivia, March 24, 1920, II, III, *451* (type); same, May 12, 1920, III, *597*; Sorata, Bolivia, April 16, 1920, II, III, *529*; La Falda, Córdoba, Argentina, August 14, 1922, II, III, *2026*.

Stipa Neesiana Trin. & Rupr., Parque Sarmiento, Córdoba, Argentina, August 11, 1922, I, *2020*.

Stipa sp., La Falda, Córdoba, Argentina, August 15, 1922, II, *2031*; same, August 20, 1922, I, II, *2039*; same August 22, 1922, II, *2040*, *2042*; same, August 24, 1922, I, 2044; same, I, II, *2045*.

O. Pycnia unknown.

I. Aecia as in Puccinia graminella, but the aeciospores slightly smaller, measuring 18–23 μ in diameter.

II. Uredinia hypophyllous, intercostal, oblong, 0.5–0.8 mm. long, early naked, pulverulent, pale cinnamon-brown, ruptured epidermis evident; paraphyses few, straight, strongly capitate, the wall colorless, uniformly thin, 1–1.5 μ, smooth; urediniospores globoid or broadly ellipsoid, 20–27 by 20–32 μ; wall cinnamon-brown, 1–1.5 μ thick, closely verrucose-echinulate, the pores 4–6, usually evident, scattered.

III. Telia hypophyllous, ellipsoid or oblong, 0.2–0.8 mm. long, early naked, pulvinate, prominent, blackish-brown, ruptured epidermis inconspicuous; teliospores ellipsoid or obovate-oblong, 18–24 by 31–45 μ, rounded or obtuse above, somewhat narrowed below, slightly constricted at septum, wall dark chestnut-brown, 1.5–2.5 μ thick, much thicker above, 6–10 μ, smooth; pedicel slender, persistent, once to twice length of spore, colored.

The aecia of this species on *Stipa Neesiana* from Montevideo, Uruguay, and La Plata, Argentina, were described by Spegazzini in 1899 (*l. c.*), under the name *Aecidium graminella*, var. *Neesiana*, and the uredinia and telia in 1902 under the name *Puccinia graminella* (An. Mus. Nac. Buenos Aires III, **1**: 63). For the latter there are two collections cited, both on *Stipa manicata*. The first of these, gathered in the summer of 1896 by J. Arechavaleta, near Montevideo, Uruguay, has been examined by the writer through the courtesy of Señor Spegazzini. The description is also given in Saccardo, Syll. Fung. **14**: 349, and is referred to by Sydow, Monog. Ured. **1**: 815. 1904.

FIG. 6. Teliospores and one aeciospore of *Puccinia digna* on *Nasella* (collection *479*). The dark-walled ellipsoid spores and the paler more oblong ones are well shown. × 500.

The aeciospores are inclined to be slightly smaller than in *P. graminella*, and the teliospores (Fig. 6) are much smaller and so far as seen without any tendency toward a pointed apex. The very abundant and colored paraphyses are especially characteristic of

the species. The collection of aecia on *Stipa hyalina* Nees, made by Spegazzini near La Plata, Argentina (An. Mus. Nac. Buenos Aires **6**: 233. 1899), may belong here. It has not been seen by the writer.

55. PUCCINIA GRAMINELLA (Speg.) Diet. & Holw.; Dietel, Erythea 3: 80. 1895.

Aecidium graminellum Speg. Hongos Sud-Am. *29*, hyponym. 1881.
Aecidium graminellum Speg. An. Soc. Ci. Arg. **12**: 77. 1881.
Puccinia graminella chilensis Neger, An. Univ. Santiago **93**: 783. 1896.
Allodus graminella Arth. Résult. Sci. Congr. Bot. Vienne 345. 1906.

Nasella chilensis (Trin.) Desv., Panamavida, Chile, December 16, 1919, I, III, *237*.

Stipa setigera Presl., Panamavida, Chile, Dec. 9, 1919, I, III, *209*; Cochabamba, Bolivia, Feb. 26, 1920, I, *328*; La Paz, Bolivia, March 19, 1920, I, *423*; Sorata, Bolivia, April 12, 1920, I, *511*; Hacienda del Urco, Urabamba Valley, Cuzco, Peru, July 4, 1920, I, *763*.

Stipa sp., Zapallar, Chile; February 1, 1920, I, III, *309*.

O. Pycnia unknown.

I. Aecia epiphyllous, scattered, cylindric or somewhat flattened; peridium colorless, erose or even deeply lacerate; peridial cells oblong in face view, rhomboidal in longitudinal section, 12–15 by 30–60 μ, slightly or not overlapping, the outer wall thick, 5–7 μ, transversely striate, the inner wall thin, 1.5–2 μ, noticeably striately verrucose; aeciospores globoid or irregularly ovoid, slightly angular, 16–25 μ in diameter; wall colorless, thick, 3–4 μ, noticeably and closely striolate-verrucose.

There are in the Holway material eleven collections of aecia on *Stipa*, six of them on *S. setigera* and one on *S. Neesiana*, while one collection is on *Nasella chilensis*. The latter genus is very closely related in habit and general appearance to *Stipa*, and leaves from species of the two genera taken by themselves could rarely be distinguished. It is therefore possible that three of the eleven collections which are imperfectly determined and are marked "*Stipa* sp.," might be either *Stipa* or *Nasella*.

The writer has also examined the type collection of aecia dis-

tributed by Spegazzini in the Hongos Sud-Americanos: Decades Mycologicae Argentinae, which also is reported as on *Stipa* sp., and therefore might be either *Stipa* or *Nasella*. The collections of aecia made at Berkeley, California, in 1894, have also been examined. These were reported as on *Stipa eminens*, but the collections have recently been reexamined and considered to be on two forms of *Stipa*, *S. lepida* and *S. lepida Andersoni*.

These several collections closely resemble one another. In fact, after careful and repeated examination and comparison, it has been impossible to find any characters by which they could be definitely segregated into recognizable groups. There are some differences in the measurements of the spores, but the spores in every collection vary between considerable extremes and the differences in measurements may only indicate variations due to favorable conditions for growth.

Six of the Holway collections on *Stipa* are accompanied by uredinia or telia, and in part on the same leaves with the aecia, which makes it possible to assign two of them respectively to each of the three species, *Puccinia graminella*, *P. digna* and *Uromyces pencanus*. The six collections unaccompanied by other spore forms have been distributed from their association with uredinial or telial collections made at about the same place and time.

The aeciospores are remarkable for their thick colorless walls and the unusual markings. They would pass at first sight as simply verrucose, as indeed they are described in the N. Am. Flora **7**: 455. 1921. By most writers, Spegazzini, Dietel and others, the spores are said to be verrucose-striolate, rugulose-striolate, or simply rugulose. The markings are not beads, but short straight ridges, as if each bead were drawn out along the surface to three or four times its breadth. These ridges sometimes anastomose.

The variety *chilensis* was founded upon material encountered but once by its author near Concepción, Chile, on *Stipa manicata*. It differs from the Californian material in having the teliospores, or part of them, prolonged above into an acuminate apex, or "cap." This collection has not been seen by the writer, but a collection found a year or so later by B. Balansa on *Stipa manicata*, at Buenos Aires, Argentina, and cited by Hennings (Hedwigia **35**: 243. 1896)

under the name *P. Stipae*, has been studied by the writer through the favor of the curator of the Berlin Museum. This collection is considered by Dietel & Neger (Bot. Jahrb. **24**: 155. 1897) as the same form as the one from Chile.

The more pronounced apical development, of the teliospore, which is sometimes narrower and paler, is to be met with in many collections, and probably has no varietal significance. Three-celled teliospores are mentioned in connection with the original description of the variety *chilensis*, but such variations are not infrequently found in other species of *Puccinia*, and probably possess no systematic importance.

The different species and forms of rusts inhabiting *Stipa* and its near relatives are of unusual interest, probably more so than of any other grass rusts. To classify them understandingly and certainly something more is needed than a morphological study, however abundant the material in hand may be. Many collections from widely separated and unlike localities, taken throughout the different seasons of the year and on many species of hosts are highly desirable. Studies in connection with the microscope and herbarium should be supplemented with careful field observations regarding possible alternate stages and hosts. These should be followed up by controlled cultures. Such cultures can best be undertaken in the region where the rusts abound and the hosts can be grown under favorable conditions, such as are to be found in many localities of South America. Such studies will not only throw light upon the species under consideration, but also have important bearings upon the course of development in all the rusts, and possibly of other fungi. It is a fascinating study that will appeal to any one fitted to undertake it, and wishing a fruitful field for scientific research.

56. PUCCINIA INTERVENIENS (Peck) Bethel; Blasdale, Univ. Calif. Publ. Bot. **7**: 119. 1919.

Aecidium Modiolae Thüm. Flora **63**: 31. 1880.
Roestelia interveniens Peck, Bull. Torrey Club **10**: 74. 1883.
Aecidium roestelioides Ellis & Ev. Jour. Myc. **1**: 93. 1885.
Aecidium Modiolae Sphaeralceae P. Henn. Hedwigia **34**: 322, hyponym. 1895.

Aecidium Malvastri P. Henn. Hedwigia **36**: 216. 1897.

Aecidium Sphaeralceae Speg. An. Mus. Nac. Buenos Aires **19**: 322. 1919; not *A. Sphaeralceae* Ellis & Ev. 1895.

Dicaeoma interveniens Arth. & Fromme, N. Am. Flora **7**: 299. 1920.

Malvastrum capitatum (Cav.) Griseb., Cochabamba, Bolivia, March 11, 1920, O, I, *397*.

Malvastrum sp., La Falda, Córdoba, Argentina, alt. 950 meters, August 21, 1922, I, *2037*.

Sphaeralcea obtusifolia Don, Zapallos, Chile, September 22, 1919, O, I, *61*.

Sphaeralcea sp., Viña del Mar, Chile, September 10, 1919, I, *17*.

Nasella chilensis (Trin.) Desv., Viña del Mar, Chile, September 10, 1919, III, *18*.

Stipa Ichu (R. & P.) Kunth, Cochabamba, Bolivia, March 11, 1920, III, *399*.

Stipa sp., La Falda, Córdoba, Argentina, August 20, 1922, III, *2038*.

O. Pycnia amphigenous, in small groups, punctiform, in section 160 μ broad by 180 μ high.

I. Aecia hypophyllous and caulicolous, in circular groups 3–6 mm. in diameter, surrounding the pycnia, large, 0.5–1 mm. high, bag-shaped, opening by a small pore, from which rifts gradually extend to the base forming long and somewhat rigid fibrillae; peridium colorless, the segments entangled but not distinctly recurved; peridial cells oblong, abutted, the outer wall very thick, 10–22 μ, smooth, the inner wall thin, 2–3 μ, noticeably striolately verrucose; aeciospores globoid, 16–27 μ in diameter; wall colorless, thick, 5–7 μ, finely but noticeably striolate-verrucose, the striae three or four times the width.

III. Telia epiphyllous, prominent, pulvinate, very large, linear-oblong, linear-fusiform, or linear, 3–10 mm. long by 1–2 mm. wide, blackish- or chocolate-brown, the ruptured epidermis inconspicuous or in long shreds; teliospores variable in shape and color, ellipsoid, rounded at both ends, dark in color, 27–30 by 35–45 μ, varying to linear-oblong or fusiform, obtuse or acuminate at both ends, pale in color, 20–24 by 48–67 μ, germinating readily, all forms not constricted at septum; wall dark chestnut-brown to pale golden-brown, often darker above, 2–3 μ thick, 4–18 μ above, smooth; pedicel colorless, once to thrice length of spore.

The proof that this rust was truly heteroecious was first demonstrated by E. Bethel by observations and cultures made in Colorado. Before that time it was confused with another heteroecious rust, *Puccinia Burnettii* (as in the N. Am. Flora 7: 299), whose aecia are on *Eurotia*.

FIG. 7. Teliospores of *Puccinia interveniens* on *Nasella* (collection *18*). The extremes in form and depth in color are fairly well shown. × 500.

Professor Holway made two strong field observations. Of the connection of numbers 397 and 399 taken in Bolivia he records in his field note book "proof perfect," and in a letter to the author, dated February 8, 1921, he says: "With 399 I began to find scattered aecia, and as I approached the big clumps of *Stipa* the aecia became more abundant, until the plants [of *Malvastrum*] next the *Stipa* were 'eaten up.' I never saw better evidence" of genetic connection. Of the Chilean collection on *Nasella* he wrote first on February 9,

1921, that "No. 18 was abundant, and the evidence just as strong," and again on January 4, 1921, "there is the most perfect proof that these [two collections] are connected with the Malvaceous aecia on nos. 17 and 397." These observations accord with similar field observations made in North America, and which have been substantiated by cultures.

The similarity, and sometimes even identity, of many characters found in the heteroecious species, *P. interveniens* and the autoecious species, *P. graminella*, is most interesting and undoubtedly significant. The teliospores in both species have the diverse forms ranging from ellipsoid and dark colored to fusiform and pale in color (Fig. 7), the latter germinating readily. The aeciospores in both species have the same thick, colorless walls and the unusual surface markings, while the aecia show the bag-shape and fibrillar dehiscence in *P. graminella*, although less strongly marked than in *P. interveniens*. The difference might be ascribed to the difference in succulence of the hosts. Undoubtedly the two species are very closely related.

The type collections of all the synonyms have been examined by the writer. That of *Aecidium Modiolae* Thüm., shows slightly smaller spores than in most collections of the species.

57. Puccinia Gymnopogonis Sydow, Monog. Ured. 1: 755. 1903.

Gymnopogon Burchellii (Munro) Ekman, Campos do Jordão, São Paulo, Brazil, April 27, 1922, III, *1779*; Mandaque, São Paulo, Brazil, May 25, 1922, III, *1888*.

From the general appearance of the telia and teliospores, and especially from the fact that no trace of urediniospores can be found, it is assumed that this species is a form without uredinia, and that it is heteroecious. It is exceedingly rare that no urediniospores can be found among the teliospores of a full-spored species, however mature the material may be at time of collection. The inferences here drawn are intended to suggest a direction for observation and study to those who have the opportunity to see the rust in the field, or who are working on it with the microscope.

The type collection was taken on *G. foliosus* Nees, Santarem, Para, Brazil, by R. Spruce. It has also been recorded by Spegazzini

on *Gymnopogon* sp. from Oran, Salta (An. Mus. Nac. Buenos Aires **19**: 297. 1909).

58. **Uromyces paspalicola** Arthur & Holway sp. nov.

Paspalum racemosum Lam., Huigra, Chimborazo, Ecuador, August 3, 1920, II, III, *823*.

O and I. Pycnia and aecia unknown.

II. Uredinia hypophyllous, usually in small groups on pale spots, oblong, 0.5–0.8 mm. long, early naked, prominent, pale yellow or whitish, somewhat pulverulent, ruptured epidermis inconspicuous; urediniospores globoid or broadly ellipsoid, small, 17–19 by 19–23 µ; wall colorless, thin, 1 µ, finely echinulate, the pores scattered, indistinct.

III. Telia hypophyllous, oblong or linear, in groups often surrounding the uredinia, 0.5–1.5 µ long, long covered by the epidermis, blackish, teliospores angularly globoid or obovoid, 20–24 by 23–29 µ; wall chestnut-brown, almost uniformly thick, 2–3 µ, smooth; pedicel thin, fragile, colorless.

59. Uromyces leptodermus Sydow; Sydow & Butler, Ann. Myc. **4**: 430. 1906.

Uredo Panici Arth., Bull. Torrey Club **29**: 231. 1902.

Uredo Setariae-italicae Dietel, Bot. Jahrb. **32**: 632. 1903.

Uromyces Setariae-italicae Yoshino, Bot. Mag. Tokio **20**: 247. 1906.

Nigredo leptoderma Arth. N. Am. Flora **7**: 224. 1912.

Uromyces niteroyensis Rangel, Arch. Mus. Nac. Rio de Janeiro **18**: 161. 1916.

Uredo Panici-maximi Rangel, Arch. Mus. Nac. Rio de Janeiro **18**: 161. 1916.

Chaetochloa caespitosa (Hack. & Arech.) Speg. (*Setaria caespitosa* Hack. & Arech.), Montevideo, Uruguay, July 29, 1922, II, *2016*.

Chaetochloa Poiretiana (Schult.) Hitchc. (*Setaria Poiretiana* Desv.), Prata, São Paulo, Brazil, April 9, 1922, II, *1720*.

Chaetochloa rariflora (Mikan.) Hitchc. & Chase (*Setaria rariflora* Mikan.), Jacarepagua, Rio de Janeiro, Brazil, alt. 100 feet, September 4, 1921, II, *1090*.

Chaetochloa tenax (L. Rich.) Hitchc. (*Setaria tenax* Desv.), Rio de Janeiro, Brazil, alt. 900 feet, August 10, 1921, II, *1013*; Gavea, Rio de Janeiro, Brazil, January 13, 1922, II, *1474*.

Lasiacis ligulata Hitchc. & Chase, Sylvestre, Rio de Janeiro, Brazil, September 16, 1921, II, III, *1117*; San Francisco, Nictheroy, Brazil, September 23, 1921, II, iii, *1148*.

Lasiacis ruscifolia (H. B. K.) Hitchc. & Chase, Guayaquil, Ecuador, July 31, 1920, II, *801*.

Panicum barbinode Trin., Santa Clara, Peru, July 23, 1920, II, *790*.

Setaria leiantha Hack., La Falda, Argentina, August 20, 1922, II, *2035*.

The species occurs throughout the warmer regions of the world on many Paniceous hosts, but rarely produces teliospores. There is considerable variation in the size and wall thickness of the spores and in the presence or absence of hyphoid paraphyses, as would naturally be expected in a species so widely distributed and on so many species of hosts. Teliospores with walls 2–3 μ thick were described by Yoshino from Japanese material as a distinct species, and the same variation is given under the name *Uromyces niteroyensis* by Rangel.

Other collections from South America represented in the Arthur Herbarium are as follows:

Chaetochloa sp. (*Setaria* sp.), Cubango near Nictheroy, Brazil, April 1914, II, iii, Rangel *1172* (*Urom. niteroyensis*).

Lasiacis ligulata Hitchc. & Chase, Nictheroy, Brazil, July 20, 1915, II, Rose & Russell *20314*.

Lasiacis sp., Gasparee Island near Trinidad, British West Indies, April 2–7, 1921, II, Seaver *3477*.

Panicum barbinode Trin., Santa Clara, Peru, July 18, 1914, II, Rose *18723*.

Panicum maximum Jacq., Icarahy near Nictheroy, Brazil, June 29, 1913, II, Rangel *749* (*Uredo Panici-Maximi*).

Uromyces Puttemansii Rangel (*l. c.*, p. 159) was founded on a collection made at Paquetá Island near Rio de Janeiro, Brazil, June 7, 1914, II, Rangel *1211*, with the host named *Panicum Melinis*, but the single leaf sent to the writer appears much more like that of *Syntherisma sanguinalis*, and this is the opinion of the critical agrostologist, Professor A. S. Hitchcock. *Uromyces Panici-sanguinalis* Rangel, (*l. c.*, p. 159) founded on *Panicum sanguinale*

(= *Syntherisma sanguinalis*) appears to be identical in both fungus and host with the preceding, judging by the material transmitted to the writer. Specimens in the Holway Herbarium also agree perfectly with those in the writer's possession. A very careful search of the four specimens mentioned failed to reveal a single teliospore. Uredinia are abundant in each case, and the urediniospores appear much more like those of *Puccinia substriata* Ellis & Barth. than of *Uromyces leptodermis*, where the illustrations published with the author's descriptions would naturally place them. The status of these two names must be left to future inquiry.

60. UROMYCES MICROCHLOAE Sydow, Ann. Myc. 1: 15. 1903.

Microchloa indica (L.) Beauv., Cochabamba, Bolivia, March 3, 1920, ii, III, *361*; same, La Paz, Bolivia, March 31, 1920, II, III, *490*.

An African rust now first reported for America.

61. UROMYCES ARGENTINUS Speg. An. Soc. Ci. Arg. 9: 170. 1880.

This species is only known from the type collection, which has been kindly loaned by Señor Spegazzini for the writer to study. It was found at Recoleta, on the Rio de la Plata, Argentina, February 25, 1880. The host was doubtfully considered to be a species of *Stipa*. The writer thinks it is either a species of *Stipa* or *Nasella*. In a paper on the flora of the mountains of Ventana, Spegazzini gives the host as *Stipa Neesiana* without comment. The paper is published by the Minister of Public Works, 1896.

Both urediniospores and teliospores are present, and both are large, with very uniformly thin walls, the former having three equatorial pores. It appears to be a well differentiated species.

62. UROMYCES IGNOBILIS (Sydow) Arth. Mycologia 7: 181. 1915.

Uredo ignobilis Sydow, Ann. Myc. 4: 444. 1906.
Uromyces major Arth. Bull. Torrey Club 38: 377. 1911.
Nigredo major Arth. N. Am. Flora 7: 225. 1912.

The only South American locality yet known for the species is the Island of Trinidad, where it was collected by Seaver in 1921, on *Sporobolis indicus* L., II, *3093*.

63. Uromyces Sporoboli Ellis & Ev. Proc. Acad. Phila. **1893**: 155. 1893.

Nigredo Sporoboli Arth. Résult. Sci. Congr. Bot. Vienne 344. 1896.

Sporobolus Berteronianus (Trin.) Hitchc. & Chase, Panamavida, Chile, October 14, 1919, II, *228*; Cochabamba, Bolivia, March 1, 1920, II, *351*; La Paz, Bolivia, March 29, 1920, II, *481*; Riobamba, Ecuador, August 10, 1920, II, III, *862*; Quito, Ecuador, August 15, 1920, II, III, *898*.

The species has not before been reported from South America. In North America cultures have been made connecting the grass form with aecia on *Allium*.

64. Uromyces Andropogonis Tracy, Jour. Myc. **7**: 281. 1893.

Aecidium (Caeoma) pedatatum Schw. Trans. Am. Phil. Soc. II. **4**: 309. 1832.

Uromyces pedatatus Sheldon, Torreya **10**: 90. 1910.

Nigredo pedatata Arth. N. Am. Flora **7**: 223. 1912.

Andropogon emersus Fourn., Cochabamba, Bolivia, February 26, 1920, II, *325*; Choisica, Peru, July 23, 1920, II, iii, *783*.

Andropogon saccharoides Berteronianus Steud. & Hochst., Cochabamba, Bolivia, March 11, 1920, II, *392*; Quito, Ecuador, August 15, 1920, II, *903*.

Andropogon saccharoides laguroides (DC.) Hack., Panamavida, Chile, December 17, 1919, II, *239, 244*.

The species has not before been reported from South America. Its aecia occur on various species of *Viola*.

65. Uromyces Epicampis Diet. & Holw.; Holway, Bot. Gaz. **24**: 23. 1897.

Nigredo Epicampis Arth. Résult. Sci. Congr. Bot. Vienne 343. 1906.

Epicampes macroura (H. B. K.) Benth., Quito, Ecuador, August 29, 1920, II, *952*.

Heretofore this species has only been known from the warmer parts of North America.

66. UROMYCES ERAGROSTIDIS Tracy, Jour. Myc. **7**: 281. 1893.

Nigredo Eragrostidis Arth. Résult. Sci. Congr. Bot. Vienne 343. 1906.

Eragrostis ciliaris (L.) Link, Raiz da Serra, Rio de Janeiro, Brazil, alt. 200 meters, November 6, 1921, II, *1281*.

Eragrostis pilosa (L.) Link, Rio de Janeiro, Brazil, September 12, 1921, II, *1104*; Bom Successo, Rio de Janeiro, Brazil, alt. 150 feet, September 13, 1921, II, *1105*.

Eragrostis virescens Presl, Cochabamba, Bolivia, March 1, 1920, II, III, *356*; same, March 6, 1920, II, III, *372*; Sorata, Bolivia, April 17, 1920, II, *539*; Huigra, Ecuador, August 3, 1920, III, *825*.

Eragrostis sp., near *E. contristata* Nees, Cochabamba, Bolivia, March 8, 1920, II, *377*; near *E. lugens* Nees, La Paz, Bolivia, March 26, 1920, II, III, *463*.

Reported here for the first time for South America. Numbers *356*, *372* and *825* show a specially heavy development of telia, indicating that aecia might possibly be found in those localities. No suggestions for the alternate host have yet been made.

67. **Uromyces bromicola** Arthur & Holway sp. nov.

Bromus coloratus Steud. Concepcion, Chile, October 29, 1919, II, iii, *150*.

O and I. Pycnia and aecia unknown.

II. Uredinia hypophyllous, scattered, oval or oblong, 0.3–0.5 mm. long, early naked, pale yellow, pulverulent, ruptured epidermis conspicuous; urediniospores broadly ellipsoid or globoid, 20–26 by 23–29 μ; wall pale yellow, 1–1.5 μ thick, often appearing thicker, finely echinulate, the pores scattered, 6–8, moderately distinct.

III. Telia amphigenous, scattered, punctiform or oblong, small, 0.1–0.3 mm. long, long covered by the epidermis, grayish; teliospores angularly globoid or oblong, 21–23 by 23–30 μ; wall chestnut-brown, almost uniformly thick, 2–3 μ, smooth; pedicel very short, thick, fragile.

The relationship of this species is uncertain. Its general morphology would place it near *Urom. argentinus*, but that species has equatorial pores in the urediniospores. There is a bare possibility that the aecial form recorded on *Bromus unioloides* from Uruguay

(Winter, Hedwigia **26**: 13. 1887) may belong here. It was collected at Montevideo, October, 1886, by J. Arechavelata, and has not been reported since. It was listed under the name *Aecidium graminellum*, and stated to agree exactly with that species.

68. **Uromyces pencanus** (Dietel & Neger) Arthur & Holway comb. nov.

Uredo pencana Dietel & Neger, Bot. Jahrb. **27**: 15. 1899.

Nasella chilensis (Trin.) Desv., San Felipe, Chile, September 25, 1919, II, III, *69*.

Nasella pubiflora (T. & R.) Desv., La Paz, Bolivia, March 18, 1920, II, *419*, *420*; same, March 26, 1920, II, *464*; same March 27, 1920, II, *476*.

Stipa manicata Desv., Zapallar, Chile, February 1, 1920, II, III, *307*, *310*.

Stipa mucronata H. B. K., Temuco, Chile, November 3, 1919, II, III, *160*.

Stipa setigera Presl, Papudo, Chile, September 16, 1919, I, II, iii, *25*; Constitucion, Chile, October 20, 1919, II, *134*; same, October 27, 1919, II, *140*; Panamavida, Chile, December 9, 1919, II, *211*; same, III, *211½*; Recinto, Chile, January 10, 1920, I, II, *287–8*.

Stipa sp., Viña del Mar, Chile, September 6, 1919, II, *8*; Cochabamba, Bolivia, February 28, 1920, II, *347*.

O. Pycnia unknown.

I. Aecia as in Puccinia graminella, but the aeciospores slightly larger, 21–30 μ in diameter.

II. Uredinia hypophyllous, intercostal, oblong, 0.5–1 mm. long, early naked, pulverulent, cinnamon-brown, ruptured epidermis evident; paraphyses none; urediniospores globoid or broadly ellipsoid, 23–29 by 26–32 μ; wall cinnamon-brown, 2–3 μ thick, closely verrucose-echinulate, the pores 6–10, usually evident, scattered.

III. Telia amphigenous, mostly hypophyllous, oblong or elongated oblong, 0.5–1 mm. long, early naked, somewhat pulverulent, chestnut-brown, ruptured epidermis usually evident; teliospores globoid or broadly ellipsoid, 18–26 by 26–38 μ, umbonate above, rounded below; wall uniformly chestnut-brown, medium thick, 2–3 μ, much thickened above, 5–11 μ, smooth; pedicel slender, persistent, once to twice length of spore, colored.

This species adds another to the remarkable variety of *Stipa* rusts. The original collection for *Uredo pencana* has not been seen by the writer, but the description is so explicit, even to the characters of the teliospores found with the urediniospores which were so few that the authors did not venture to regard them as certainly belonging with the uredinia, that there is no chance for doubt regarding the application of the name. The original material was collected by Neger at Concepcion, Chile, on *Stipa manicata*. The teliospores are well shown in the Holway *307* (Fig. 8).

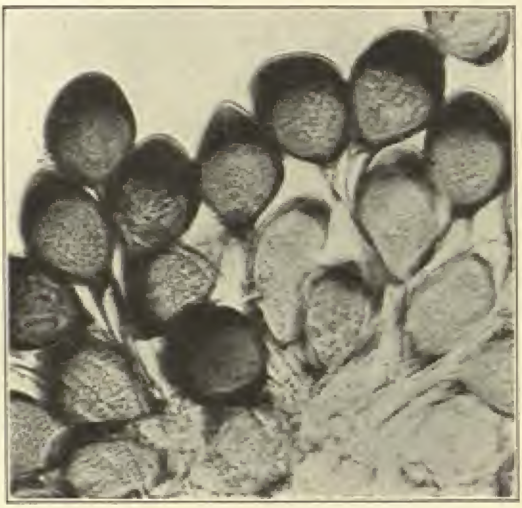

FIG. 8. Teliospores of *Uromyces pencanus* on *Stipa* (collection *307*). × 500.

As in the other *Stipa* rusts having uredinia, there is a wide variation in the size and wall-thickness of the urediniospores. In general the larger the spores the thicker the walls are likely to be, and the more indistinct the pores.

The presence of aecia in two collections, both on *Stipa setigera* and from Chile, appears to leave no doubt that the aecia belong with this species, and not with some species of *Puccinia*, especially as in No. 287–8 both aecia and uredinia are found on the same leaf. As remarked elsewhere, the *Stipa* rusts are greatly in need of study by means of cultures.

69. UROMYCES CUSPIDATUS Wint., Hedwigia **26**: 15. 1887.

Uromyces fuegianus Speg. Bol. Acad. Nac. Ci. Córdoba **11**: 181. 1888.

Undetermined composite, Termas de Chillan, Chile, alt. 2300 meters, December 29, 1919, O, I, *256*; same, December 31, 1919, O, *256a*.

Festuca dissitiflora Steud., La Paz, Bolivia, May 13, 1920, II, III, *602*.

Festuca bromoides L., Maipo Valley near Santiago, Chile, October 2, 1919, II, *78*.

Festuca Hieronymi Hack., La Paz, Bolivia, March 24, 1920, II, III, *460*; same, March 28, 1920, II, *473*, *477*.

Festuca lasiorrhachis Pilger, La Paz, Bolivia, ii, III, *604*.

Festuca megalura Nutt., Papudo, Chile, September 17, 1919, II, *27*; San Felipe, Chile, September 25, 1919, II, *68*; Maipo Valley near Santiago, Chile, October 2, 1919, II, *79*.

Festuca Myuros L., Puerto Varas, Chile, November 21, 1919, II, *180*.

Festuca procera H. B. K., Termas de Chillan, Chile, December 31, 1919, III, *260*.

Festuca rigescens (Presl) Kunth, La Paz, Bolivia, March 29, 1920, II, *483*; same, April 1, 1920, II, *491*.

Festuca sp., Temuco, Chile, November 3, 1919, II, *162*; La Paz, Bolivia, March 20, 1920, II, *434*; same, March 28, 1920, II, *480*; same, May 16, 1920, II, III, *607*.

Melica laxiflora Cav., Viña del Mar, Chile, September 5, 1919, II, III, *3*; same, September 6, 1919, II, *10*; Papudo, Chile, September 20, 1919, II, *58*; Temuco, Chile, November 3, 1919, II, *159*; Panamavida, Chile, December 12, 1919, II, *223*.

Muhlenbergia dubia Fourn., Sorata, Bolivia, April 16, 1920, II, iii, *530*.

Muhlenbergia rigida (H. B. K.) Kunth, Sorata, Bolivia, April 13, 1920, II, iii, *514*.

The original collection of this species was obtained at Cape Horn, the southernmost part of South America (Hariot 7), on *Festuca*

Commersonii Spreng. A specimen has not been seen by the writer, but the description given by Winter is that of the condition in Holway *260* (Fig. 9), many of the teliospores being narrow and

FIG. 9. *Uromyces cuspidatus* on *Festuca* (collection *260*), showing pale, narrow teliospores.

acuminate. The collection made by Spegazzini on Staten Island, Tierra del Fuego, Argentina, on *Festuca purpurascens* Banks & Sol., which has not been seen by the writer, agrees in its description with a collection on the same host, made by Thaxter, in the same general region, at Punta Arenas, Magellanes, Chile, March, 1906, which has an abundance of teliospores, both collections agreeing perfectly with the Holway *3* (Fig. 10).

As stated by Spegazzini (*l. c.*) the two forms are very similar, and from what we now know of other species the differences are to be explained by adaptation to conditions for germination.

The species is clearly related to *Urom. graminis* (Niessl) Dietel, which occurs on *Melica* in various parts of southern Europe. The agreement extends to all the sori and spores, and is especially notable in regard to the aecia, which have been proven by cultures for the European form to occur on umbelliferous hosts. These aecia, like those of *Urom. cuspidatus*, which are on composite hosts, open by pores in pustular swellings of the host, and the fragile, evanescent peridium is extruded, soon to disappear.

Again a most remarkable resemblance is to be seen between *Urom. fuegianus* and *Puccinia Stipae*, the latter not yet detected in

South America. The gross appearance, as well as the minute structure of their aecia are the same in both species, both occurring on various composites. The urediniospores and teliospores are also similar, of course making allowance for two cells in teliospores of the *Puccinia* and one cell in those of *Uromyces*. As in the case of the *Uromyces*, so with the *Puccinia*, a species like *P. Stipae*, *i.e.*, *P. stipina* Tranz., occurs in Europe, but its aecia are on labiates.

FIG. 10. *Uromyces cuspidatus* on *Melica* (collection 3), showing dark, irregularly globoid teliospores.

This, then, is the curious four-cornered situation. Four species of rusts, having very similar if not identical morphological characters occur in different areas, the sporophytic stages being on essentially the same group of hosts for the two southern species and a different group for the two northern species, but the gametophytic stages on three wholly unrelated host-families. *Urom. cuspidatus* in South America has aecia on composites, in Europe the similar *Urom. graminus* has aecia on umbellifers. *Puccinia Stipae* in North America has aecia on composites, while in Europe, especially northeastward, the similar *P. stipina* has aecia on labiates.

70. UREDO POIOPHILA Speg. Contr. Flora Sierra Ventana 84. 1896.

The original collection, not seen by the writer, was obtained at the mouth of the Cueva del Toro, Argentina, on *Poa lanigera* Nees. It appears to be well characterized by the very thin colorless walls of the spores. No other collections are known to the writer at all similar.

71. UREDO IGNAVA Arth. Bull. Torrey Club **46**: 121. 1919.

Dicaeoma ignavum Arth. & Fromme, N. Am. Flora **7**: 341. 1920.

Three collections of this species have been made in Trinidad, British West Indies. One collection on *Dendrocalamus giganteus* Munro, in 1913, by Thaxter *49*, and two on *Bambos* sp., in 1921, by Seaver *2958*, *3111*. It is an inconspicuous rust.

72. **Uredo rubida** Arthur & Holway sp. nov.

Andropogon condensatus H. B. K., Petropolis, Brazil, alt. 700 meters, October 30, 1921, II, *1256*.

Uredinia hypophyllous, or chiefly so, on reddened spots, scattered or forming lines, elongate-oblong or linear, 0.5–5 mm. long, early naked, reddish- or chestnut-brown, pulverulent, ruptured epidermis noticeable; urediniospores ellipsoid or globoid, 20–23 by 22–27 μ; wall chestnut-brown, moderately thick, 3 μ, evenly and noticeably echinulate, the pores 2, equatorial, generally distinct.

73. UREDO SETARIAE Speg. An. Mus. Nac. Buenos Aires **23**: 33. 1912.

Only the original collection is known, of which Dr. Spegazzini kindly sent the writer a portion. It was secured near Catamarca, Argentina, December, 1909, on *Setaria macrostachya* H. B. K. (a synonym of *Chaetochloa macrostachya* (H. B. K.) Scribn. & Merr.). The echinulate surface of the spores clearly distinguishes this from *Puccinia Setariae*, which has urediniospores that are unquestionably verrucose. Both forms have scattered pores in the urediniospores.

74. UREDO PANICI-URVILLEANI Dietel & Neger, Bot. Jahrb. **27**: 15. 1899.

I have had the privilege of examining a portion of the original collection, which was made by Neger, near Yumbel, Chile, on *Panicum Urvilleanum* Kunth. The spores have colored walls, 2–3 μ thick, verrucose, with 2 or 3 equatorial pores.

RUST INDEX.

Synonyms are in *Italics*, and new names and combinations in **black type**.

Host Index.

Synonyms are in *Italics*.

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A SUMMARY OF THE NOMENCLATURE AND STRATIGRAPHY OF THE MARINE TERTIARY OF OREGON AND WASHINGTON.

By LEO G. HERTLEIN in collaboration with COLIN H. CRICKMAY.

CONTENTS.

INTRODUCTION.

The purpose of this paper is to present a summary of the nomenclature and stratigraphy of the Marine Tertiary of Oregon and Washington. In certain cases different names have been applied to the same formations by different writers. Also different opinions as to the age of the various formations have been held by different workers. It is therefore attempted to give a synopsis of the nomenclature and stratigraphy of the different formations and to present a summary of the important literature on these formations. The writers aim chiefly to make such literature better understood by

those unfamiliar with the geology of the marine Tertiary of the northwest.

The work on this paper was carried out during the year of 1924. The writers have had access to the Paleontological collections of the Leland Stanford Junior University. Information has been added by the writers where additional information has been brought out by a study of the collections and of the literature.

The writers wish to thank Prof. James Perrin Smith of the Leland Stanford Junior University for his kind help in the preparation of this paper. It was at his suggestion and under his direction that the work was carried out.

Bellingham Beds.

The type locality of the lowest recognized Eocene on the Pacific coast of the United States is near the town of Martinez in California. This is a marine formation and is composed of about 1,700 feet of sandstone which is often glauconitic, a little shale and a few lenses of limestone. This formation has been well described by Dickerson [1] and others and the fauna is well known. A few typical Martinez fossils are: *Flabellum remondianum* Gabb, *Cucullaea mathewsoni* Gabb, *Lima perrini* Waring, *Tellina undulifera* Gabb, *Venericardia planicosta* var. *venturaensis* Waring, *Brachysphingus liratus* Gabb, *Perissolax blakei* Conrad, *Turbinella crassitesta* Gabb, *Turritella martinezensis* Gabb, *Turritella pachecoensis* Stanton, *Turritella simiensis* Waring. This fauna is considered subtropical.

No continental Martinez beds have been recognized in California and no marine Martinez has been recognized in Oregon or Washington. There is, however, a possibility that the continental beds at Bellingham Bay may represent the same epoch as the Martinez of California and thus prove to be a continental Martinez equivalent.

The fossil leaves from the coal beds at Bellingham were first described by Lesquereux [2] in 1859. The leaves were considered as being Miocene in age on a comparison with some of the European Miocene leaves. Newberry [3] also held this opinion. In 1898

[1] Univ. of Cal. Pub., Bull. Dept. Geol., Vol. 8, No. 6 (1914), p. 61–180.

[2] *Am. Jour. Sci.*, Vol. 77 (1859), pp. 359–363.

[3] Pac. R. R. Repts., Vol. 6, Geol., p. 64 (1857). *Boston Jour. Nat. Hist.*, Vol. 7 (1859–63), p. 509.

Newberry [4] considered the beds at Bellingham as belonging to the "Puget Group." These beds at Bellingham were considered as Cretaceous in age.

Some of the recognized leaves from Bellingham are: *Acer trilobatum?* (Al Braun), *Anemia elongata* Newberry, *Cinnamomum heeri* Lesqx., *Cinnamomum crassipes* Lesqx., *Diospyros lancifolia* Lesqx., *Glyptostrobus europaeus* (Brogn.) Heer, *Nyssa? cuneata* Newberry, *Nilsonia gibbsii* (Newberry) Hollick, *Sequoia cuneata* Newberry, *Sequoia spinosa* Newberry, *Sabalites campbelli* Newberry, *Populus rhomboidea* Newberry. Leaves from Chuckanutz are: *Populus flabellum* Newberry, *Quercus banksiaefolia* Newberry, *Quercus washingtonensis* (Newberry) Trelease, *Quercus flexuosa* Newberry.

The flora from Bellingham appears to be later than Cretaceous and earlier than known middle Eocene flora. The Chuckanutz flora appears to be later than the leaves from Bellingham and it is possible that there are different beds exposed near Bellingham which represent different periods. It is quite possible that the Bellingham flora may represent a lower Eocene age which might possibly belong to the same epoch as the Martinez formation of California. The writers realize that these beds are non-marine but owing to their importance and proximity to the coast they have been included in this paper.

Arago Formation.

The fossiliferous beds at Cape Arago and those of the Umpqua river were early known to Prof. Thomas Condon of the University of Oregon. C. A. White in 1889 [5] stated that Condon had discovered characteristic Eocene fossils at Cape Arago such as *Venericardia planicosta*. In 1896 Diller [6] named the beds which were so well exposed at Cape Arago, the Arago beds. Diller stated that the Arago beds extended south from Cape Arago nearly to the mouth of Coquille river, but do not outcrop on the coast north of Cape Arago. The same series was also reported as outcropping near Roseburg and at points in the Willamette valley. The beds

[4] U. S. Geol. Surv., Mon. No. 35 (1898), p. 15.

[5] U. S. Geol. Surv., Bull. 51 (1889), p. 29.

[6] U. S. Geol. Surv., 17th Ann. Rept., Pt. 1 (1896), pp. 458–462.

near Ilwaco were also referred to the Eocene by Dall. Fossils identified from the beds at Cape Arago by Dall and listed by Diller are: *Modiola ornata* Gabb, *Venericardia planicosta* Lam., *Pectunculus veatchii* Gabb, *Turritella uvasana* Con., species of *Thracia, Diplodonta, Callista* and *Leda*.

In 1898 Dall [7] stated that the Arago beds averaged over 3,000 feet in thickness. He further stated that the Arago suggested a correlation with the Claiborne of the Gulf States. According to Dall the Arago appeared to be newer than the beds about the junction of Little river and the North Umpqua.

Diller in 1899 [8] separated the Arago into two divisions; the early part of the Arago he called the Pulaski, and the later coal bearing part of the Arago, which contains many brackish water fossils, he called the Coaledo. Diller [9] stated in another paper, that the Arago beds exposed near Cape Arago were 10,000 feet thick.

In 1907 [10] Diller mentioned that fossil leaves occur interbedded with the marine Arago beds. A list of these leaves was published in Prof. Paper No. 73.[11] The following leaves were listed; *Aralia angustiloba* Lesqx.?, *Aralia whitneyi* Lesqx., *Ficus tiliaefolia* Al Braun, *Laurus californica* Lesqx.?, *Magnolia californica* Lesqx., *Magnolia lanceolata* Lesqx., *Populus zaddachi* Heer, *Sabalites californica* Lesqx.? These leaves were found interbedded with marine beds containing *Turritella uvasana* Con., and *Venericardia planicosta* Lam., and were therefore assigned to the Eocene.

In 1901 Diller [12] discussed the Arago formation in the Coos Bay folio. In 1903 in the Port Orford folio Diller [13] mentions that while the Arago beds near Cape Arago are 10,000 feet in thickness, in the Port Orford region they probably average less than one half that amount. His conclusion was that during the deposition of these beds the sea was shallow and alternated between sea and dry land upon which the coal building plants grew.

[7] U. S. Geol. Surv., 18th Ann. Rept., Pt. 2 (1898), p. 343.

[8] U. S. Geol. Surv., 19th Ann. Rept., Pt. 3 (1899), pp. 319–320.

[9] *Geol. Soc. Amer.*, Vol. 4 (1898), p. 219.

[10] *Proc. Wash. Acad. Sci.*, Vol. 8 (1907), p. 405.

[11] U. S. Geol. Surv., Prof. Paper No. 73 (1911), p. 64.

[12] U. S. Geol. Surv., Coos Bay Folio No. 73 (1901), pp. 2, 3.

[13] U. S. Geol. Surv., Port Orford Folio No. 89 (1903), p. 3.

In 1913 Arnold and Hannibal [14] stated that the type section of the Arago is taken across the strike of a steeply dipping fault block and that it may be estimated to include about 10,000 feet of alternating marine and fresh water beds which are partly arkosic and partly tuffaceous in character. The base and top of the formation are not exposed. According to Arnold and Hannibal the formation extends eastward to the base of the Cascades and might represent 15,000 feet of sediments. The Arago, according to their report, also outcrops at points in the Willamette valley and in the coast ranges. They found that as the Arago formation is traced northward it is replaced by basic flows and agglomerates and that on the Santiam River east of Albany and on the Nehalem river in Columbia and Clatsop counties only igneous rocks are present. In the correlation table Arnold and Hannibal include under the Arago formation all of Diller's Eocene including the Umpqua formation. The Arago they recognized as a division of the Tejon and placed it at the top of the Tejon series and considered the Crescent formation of northern Washington as the equivalent of the Arago formation of Oregon. These formations were considered to be middle Eocene in age. Some of the fossils collected from the type section of the Arago formation by H. Hannibal are; *Crassatellites uvasana* Conrad, *Macrocallista conradiana* Gabb, *Modiolus ornatus* Gabb, *Ostrea idriaensis* Gabb, *Solen parallelus* Gabb, *Tellina horni* Gabb, *Tellina remondi* Gabb, *Venericardia planicosta* var. with obsolete ribs (evidently var. merriami Dick.) *Ficopsis horni* Gabb, *Polinices horni* Gabb, *Sinum obliquum* Gabb, *Strepsidura whitneyi* Gabb, *Turris io* Gabb, *Turritella uvasana* Con., *Dentalium stramineum* Gabb. Several localities yielding flora in Oregon were also thought to belong to this horizon, namely "The Benton County hills a mile north of Granger, Oregon, Mary's Peak near Philomath, the Willamette River above Springfield, and the north Santiam River between Lyons and Kingston. . . ." Also localities near Comstock in Douglas County and on Coal Creek in Lane county. Several localities near Ashland were thought possibly to represent the same horizon. Some of the flora collected at Mary's Peak by Harold Hannibal is as follows; *Acer minor* Kn., *Alnus corralina* Lesqx.,

[14] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), pp. 571–573.

Betula aequalis Lesqx., *Laurus californica* Lesqx., *Laurus princeps* Heer, *Platanus* sp., *Quercus nevadensis* Lesqx., *Quercus breweri* Lesqx., *Salix angusta* Al. Braun, *Salix varians* Göppert, *Sequoia angustifolia* Lesqx., *Ulmus speciosa* Nby. The leaves listed by Knowlton from near Comstock in Douglas County and on Coal Creek in Lane county were thought to be of the Arago horizon and not Miocene as suggested by Knowlton. From Coal Creek Knowlton [15] lists; *Acrostichum simulatum* Kn., *Asplenium tenerum?* Lesqx., *Sequoia angustifolia?* Lesqx. From Comstock Knowlton lists; *Cinnamomum dilleri* Kn., *Ficus* cf. *sordida* Lesqx., *Ficus* sp. *Juglans* sp. *Laurus similis* Lsqx., *Rhus mixta* Kn. From the Santiam river locality leaves have been collected by H. Hannibal such as; *Alnus* sp., *Benzoin dilleri* Kn., *Cinnamomum bendirei* Kn., *Cinnamomum* sp., *Corylus macquarri* Heer, *Corylus* sp., *Laurus similis* Kn., *Magnolia inglefieldi* Heer, *Onoclea sensibilis fossilis* (Newby), *Quercus dubia* Newby., *Quercus applegatei* Kn., *Persea punctulata* Lesqx.

In 1914 Arnold and Hannibal [16] considered the Arago formation of Oregon and the Ione formation of California as of the same age. Clark [17] considered the Ione as referred to by Arnold and Hannibal as Meganos, middle Eocene in age.

It appears to the writers that the Arago of Oregon and the Meganos of California are of the same age. The flora listed from the Arago is of a subtropical character and several of the species are identical with those of known Meganos beds in Corral Hollow, California. The fauna also appears to represent the same horizon. If the type section of the Arago contains the same species as the type Meganos, the name Arago should be used for the standard middle Eocene of the Pacific northwest coast. A complete study of the Arago has not been made but it appears to be the same horizon as the Meganos of California.

Umpqua Formation.

The fossiliferous beds on the Umpqua River were early known to Prof. Thomas Condon. In 1893 Diller [18] referred the Umpqua

[15] U. S. Geol. Surv., 20th Ann. Rept., pt. 3 (1900), pp. 37–64, Pl. I.–V.; U. S. Geol. Surv., Bull. 204 (1902), p. 111.

[16] *Science*, N. Ser., Vol. 39, No. 1016 (1914), p. 607.

[17] *Jour. Geol.*, Vol. 29 (1921), pp. 125–165.

[18] *Bull. Geol. Soc. Amer.*, Vol. 4 (1893), p. 219.

beds to the Tejon group. In 1896 Diller [19] included the Umpqua beds with the Arago and apparently considered them as the eastern extension of the Arago beds which occurred on the coast. In 1898 Dall [20] stated that the Umpqua beds might be of a different age and that they probably needed to be separated from the Arago. He also added that the Arago beds appeared to be newer than the beds about the junction of Little River and the north Umpqua. Thus he evidently thought that the Umpqua beds were older than the Arago beds.

In 1898 Diller [21] described the Eocene beds in the Roseburg quadrangle under the names of four formations. The lowermost he called the Wilbur Tuff-Lentils. This formation is made up mostly of volcanic material with some calcareous and siliceous and organic sediments. The Wilbur Tuffs Lentils according to Diller is interbedded with the Umpqua formation and is of small extent and slight thickness.

The Umpqua formation is composed of about 12,000 feet of thin bedded sandstones and shales, locally containing coal seams and some conglomerates. This formation is well exposed near the mouth of Little River at its junction with Umpqua River, near Roseburg, Oregon. The lower 4,500 feet of the formation is separated from the upper part by diabase which was extruded in the Eocene. The Umpqua formation lies unconformably upon the upturned and eroded edges of the Cretaceous Myrtle formation. According to Diller the Umpqua formation becomes thicker to the northwest and has a wide distribution throughout the coast range. It extends to the northeast and dips under the lava at the western foot of the Cascade range. It also extends up Little River and appears in patches at many places. These patches according to Diller represent a sheet which was once continuous and covered the older rocks to the southeast. Conglomerates are not common. They occur in the southeastern part of the mass, or close to the diabase, and according to Diller are made up of pebbles of the Myrtle formation and in part from the diabase. Most of the

[19] U. S. Geol. Surv., 17th Ann. Rept., Pt. 1 (1896), pp. 458–462.

[20] U. S. Geol. Surv., 18th Ann. Rept., Pt. 2 (1898), p. 343.

[21] U. S. Geol. Surv., Folio No. 49 (1898), p. 2, 3.

sandstone beds are not over 50 feet thick and are thought by Diller to represent oscillating conditions of the sea during the deposition of the Umpqua formation.

In 1885 White[22] stated that Condon had discovered beds with *Venericardia planicosta* near Albany, Oregon, in the Willamette valley.

Overlying the Umpqua formation Diller reported the Tyee sandstone which has a thickness of about 1,000 feet. He stated that the Tyee sandstone differs from the Umpqua formation mainly in the fact that it is of heavier bedding and that it contains more conspicuous scales of mica. He also reports a layer containing leaf impressions near the middle of the Tyee formation. Characteristic Eocene fossils occur in the Tyee formation such as; *Venericardia planicosta* Lam., etc. The youngest Eocene mentioned by Diller is the Oakland limestone-lentils. Three extremely small patches widely separated are reported. These patches were reported as not exceeding an acre in area. These lentils were thought to lie conformably upon the Umpqua formation by Diller but evidence of the fossils given by Dall lead Diller to suggest that the lentils may lie unconformably upon the Umpqua. He lists; *Corbula*, *Lucina*, *Natica*, *Turritella*, *Venus*, and says that the fossils are not typical Eocene according to Dall but are likely upper Oligocene.

In 1913 Arnold and Hannibal[23] included the Umpqua beds under the Arago formation. The Wilbur Tuff-Lentils according to them is a lithologic phase of the Arago which is common where fossil beds rest upon basic igneous flows and tuffs. H. Hannibal collected Eocene fossils near Glide, Oregon, from the bluffs along Little River. Some of the species listed as common to both the Arago and Umpqua formations by Arnold and Hannibal are; *Crassatellites compacta* Con., *Macrocallista conradiana* Gabb, *Modiolus ornatus* Gabb, *Ostrea idriaensis* Gabb, *Solen parallelus* Gabb, *Venericardia horni* var. with obsolete ribs, *Ficopsis horni* Gabb, *Turritella uvasana* Con. Arnold and Hannibal included the Tyee under the Arago formation and stated that probably it is the same horizon as the Umpqua formation. According to them the

[22] U. S. Geol. Surv., Bull. 18 (1885), pp. 7–9.

[23] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), pp. 571–573, 603.

Oakland limestone-lentils can only be considered as a local division.

In 1914 Washburne[24] stated that the Tyee formation could be found from its type locality in Douglas county south to the Rogue river mountains and north over 120 miles into Tillamook county. He thought it not improbable that the upper Eocene of the lower Columbia might be of the same age. He stated that there were a few thin beds of lignite coal present in the formation. Washburne estimated the thickness of the Tyee formation on the Siuslaw and Alsea Rivers as at least 2,000 feet and the base was not exposed; at some places he thought it might be thicker. Considerable fresh water sediment in parts of the formation north of the Umpqua River was mentioned.

In 1914 Dickerson[25] described a fauna from the Umpqua formation. The fauna came from two localities, one on the Umpqua River near the mouth of Little River, and the other locality ¼ mile north of Glide, Oregon. This fauna was from the upper part of the Umpqua formation, probably, 10,000 feet from the bottom. According to Dickerson the fauna is the equivalent of the lower part of the *Siphonalia sutterensis* Eocene zone of the Marysville Buttes in the northern part of the great valley of California.

In 1921 Clark[26] stated that the Siphonalia sutterensis zone of the Eocene of Marysville Buttes and the fauna of the Roseburg quadrangle were the equivalent of the Meganos of the Mt. Diablo region of California. The Meganos was formerly considered as lower Tejon.

A comparison of faunal lists from the Umpqua formation and from the Marysville Buttes shows such species in common as; *Cardium breweri* Gabb, *Cardium marysvillense* Dick., *Modiolus ornatus* Gabb, *Venericardia planicosta* var. *merriami?* Dick., *Amauropsis alveata* Gabb, *Ancilla (Oliverato) californica* Cooper, *Caricella stormsiana* Dick., *Chrysodomus martini* Dick., *Ficopsis remondi* Gabb, *Siphonalia sutterensis* Dick., *Surcula davisiana* Cooper, *Turritella merriami* Dick., *Turris saturnalis* Cooper.

It appears that the Umpqua beds are of approximately the same horizon as the *Siphonalia sutterensis* zone of the Marysville Buttes

[24] U. S. Geol. Surv., Bull. 590 (1914), p. 10.

[25] *Proc. Cal. Acad. Sci.*, 4th Ser., Vol. 4 (1914), pp. 113–128.

[26] *Jour. Geol.*, Vol. 29 (1921), p. 162.

and are probably the eastern extension of the Arago formation, although they may be slightly lower than the Arago. There is a possibility that the Oakland limestone lentils represent the same epoch of deposition as the limestone near Dallas, Oregon. The Dallas limestone appears to be a lens, containing numerous foraminifera many of which belong to the Genus *Operculina*.

Crescent Formation.

The Crescent formation was described by Arnold[27] in 1906. This formation consists of a series of black basalt and greenish basaltic tuffaceous sands which are found in the vicinity of Port Crescent, Washington. This formation was reported as occupying the region immediately west of Port Crescent Bay to Fresh water Bay. *Venericardia planicosta* Lam., and *Turritella uvasana* Con., and other characteristic Eocene fossils were found in the Crescent formation. These fossils were considered as Eocene and contemporaneous with the Tejon of California. The base of the Crescent formation is not exposed and it is separated from the beds above by an erosion interval. Arnold also reported that a fault forms the boundary between the Crescent and Clallam formations. Reagan[28] accepted this status of the Crescent formation in a paper in 1908.

In 1913 Arnold and Hannibal stated that the Crescent formation was the stratigraphic equivalent of the Arago of Oregon. Some of the fossils occurring in both the Arago and Crescent formations are as follows; *Macrocallista conradiana* Gabb, *Modiolus ornatus* Gabb, *Ostrea idriaensis* Gabb, *Venericardia planicosta* (var. with obsolete ribs), *Turritella uvasana* Con. A few other species listed from the Crescent formation are; *Corbula horni* Gabb, *Glycimeris cor* Gabb, *Marcia quadrata* Gabb, *Septifer dichotomous* Gabb, *Amauropsis alveata* Con., *Calyptraea excentrica* Gabb, *Polinices globosa* Gabb, *Polinices shumardiana* Gabb, *Tritonium californicum* Gabb, *Terebratula tejonensis* Stanton.

[27] *Bull. Geol. Soc. Amer.*, Vol. 17 (1906), p. 460.

[28] *Trans. Kans. Acad. Sci.*, Vol. 22 (1909), pp. 162–163.

Cowlitz Formation.

The name Cowlitz formation was first given to the marine Eocene beds in the Cowlitz valley in Washington by Weaver [29] in 1912. He stated that there were two divisions of the Eocene in western Washington, the older was the Cowlitz and the younger the upper Tejon and that both were upper Eocene. These formations he stated, were composed of sandstone, shale and conglomerate and small amounts of shaly limestone and intercalated tuff and basaltic lava. These beds are partly marine and partly brackish water deposits. The Eocene stata according to Weaver outcrop over an area of 4,000 square miles and are much covered by glacial drift. The marine sediments prevail in western Lewis county, Cowlitz, Wahkiakum, eastern Pacific and Chehalis and western Thurston counties. These beds thin out to the east and are replaced by brackish water deposits on the western slope of the Cascades and at some places fresh water beds are present. Weaver stated that in the western part of King county there are marine beds with a Tejon fauna and that in southern Lewis county east of Little Falls there are shales and shaly limestones with a fauna older than the typical Tejon but closer to the Tejon than the Martinez, these he called the Cowlitz beds. He suggested that this might be a transitional fauna. According to Weaver the basaltic lava and tuffs within the Eocene of western Washington have a thickness of 1,500 to 2,000 feet.

In 1913 Arnold and Hannibal [30] divided the Eocene of the Cowlitz valley into two formations. The lower part they called the Chehalis formation. This name used by Lawson several years earlier, was adopted by Arnold and Hannibal. Lawson [31] used the term Chehalis sandstone for some beds containing marine Eocene fossils exposed in a water tunnel through the hill east of the city of Chehalis, Washington. The upper division Arnold and Hannibal called the Olequa formation. The type section they state extends "from the Ewing ranch a little over two miles above Little Falls southward down Olequa Creek to Olequa, a distance of about five

[29] Wash. Geol. Surv., Bull. 15 (1912), pp. 12–13.

[30] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), pp. 565–571.

[31] *Amer. Geol.*, Vol. 13 (1894), p. 437.

and one-half miles." The fauna of the Chehalis and Olequa were found to be quite similar but the flora markedly different. The fauna from the type Tejon of California was thought to represent the same faunal stage as the Chehalis fauna. The Olequa formation according to Arnold and Hannibal contained subtropical plants such as palms, while the Chehalis contained flora with birches, maples and elms suggesting a more temperate climate. They also suggest that the Olequa and Swauk formations may have been deposited at the same time as suggested by the similarity of the flora, especially the palms.

In 1915 Dickerson [32] made a comparative study of the fauna of the Cowlitz beds with that of the Tejon of California. He thought that the Cowlitz beds were of the same age as the beds at the type locality of the Tejon at Canada de las Uvas in California. He was of the opinion that both the Cowlitz and the type Tejon fauna belonged to the middle Tejon and he called it the *Rimella simplex* zone on account of the numerous gastropods of the species, *Rimella simplex* Dickerson. He found that 55 of the species of the Cowlitz formation occur in the Tejon of California.

In 1916 Weaver [33] gave a brief discussion of the Eocene of western Washington. In a slightly later paper Weaver [34] gave the results of a study of the Eocene from the town of Winlock south to Castle Rock a distance of about 15 miles; by an instrumental survey he proved that the Olequa formation of Arnold and Hannibal underlies the Chehalis formation. He stated that the Cowlitz formation consisted of about 10,000 feet of interbedded marine and brackish water beds which form a northeast low dipping monocline and that probably it was the southwest limb of a broad syncline and that the northeast limb occurs near Chehalis and Centralia. He found that there was about 6,000 feet of shale and sandstone of Upper Eocene age and that underlying these beds between Olequa and Castle Rock there might be approximately 6,000 feet of unmeasured Upper Eocene sandstones and shales. Between Olequa and Winlock he found the following section, from bottom to top:

[32] *Proc. Calif. Acad. Sci.*, 4th Ser., Vol. 5, No. 3 (1915), pp. 39–51.

[33] *Univ. of Wash. Pub. Geol.*, Vol. 1, No. 1 (1916), p. 3.

[34] *Proc. Calif. Acad. Sci.*, 4th Ser., Vol. 6, No. 1 (1916), pp. 1–17.

400 feet marine beds.
550 feet brackish water beds.
300 feet fresh water beds.
520 feet brackish water beds.
2,450 feet marine beds.

All the beds are fossiliferous, and Weaver stated that they are closely related to the Middle Tejon of the Mount Diablo region of central California. The basement upon which the strata were deposited is not known. The contact with the overlying beds is not seen as it is covered, but Weaver stated that the fauna is closely related to the overlying *Molopophorus lincolnensis* zone of the Lower Oligocene north of Lincoln Creek in Thurston County. Overlying the Eocene in the vicinity of Winlock and at Greece ranch on the Cowlitz River are marine beds of Oligocene age. In another paper Weaver [35] gave a brief review of the literature of the Tertiary of western Washington, and stated that he did not think that there was sufficient evidence for dividing the Tejon of western Washington into two groups, although there might be several zones there. He also stated that between Olequa and Winlock the marine faunas have their closest relationship to the *Siphonalia sutterensis* zone of the Tejon of California. He also stated that corals are unknown in the Eocene of Washington. The genera found in the Eocene are mostly gastropods and pelecypods, of the genera that occur in the littoral or sublittoral zones. Weaver was of the opinion that theclimate became cooler toward the end of the Tejon; this floral difference had been noted earlier by Arnold and Hannibal. Weaver thought that the depths of the water ranged from estuarine basins to possibly 100 fathoms.

Partial lists of the fauna and flora of the Cowlitz beds are given in this paper. The flora was collected by Mr. Harold Hannibal. It would seem that an arbitrary line should be drawn through the fresh water beds which occur between the Olequa and Chehalis formations thus separating them if they are to be recognized as separate formations. A study of the Chehalis flora seems to suggest that it may represent an epoch somewhere near the equivalent of the Jackson. The writers are of the opinion that the Olequa may represent a Tejon age while the Chehalis may possibly represent a higher horizon corresponding to the Jackson of the east coast.

[35] Wash. Geol. Surv., Bull. No. 13 (1916), pp. 85–163.

Partial List of Species from the Olequa and Chehalis Formations and their Occurrence in the Type Tejon. Tejon List from Dickerson.

	Olequa.	Chehalis.	Calif. Tejon.
Terebratulina washingtoniana Wvr.		×	
Avicula pellucida Gabb.		×	×
Barbatia morsei Gabb.	×	×	×
Cardium breweri Gabb.	×	×	×
Corbula horni Gabb.	×	×	×
Crassatellites grandis Gabb.	×	×	×
Crassatellites washingtoniana Wvr.	×	×	
Glycimeris sagittata Gabb.	×	×	×
Leda gabbi Conrad.	×	×	×
Marcia quadrata Gabb.	×	×	×
Macrocallista conradiana Gabb.	×	×	
Meretrix? horni Gabb.	×	×	
Meretrix? uvasana Conr.	×	×	×
Modiolus ornatus Gabb.	×	×	×
Ostrea idriaensis Gabb.	×	×	×
Pecten cowlitzensis Wvr.		×	
Pecten landesi Arnold.	×	×	
Septifer dichotomus Gabb.	×	×	
Solen parallelus Gabb.	×	×	×
Tellina horni Gabb.	×	×	
Venericardia planicosta horni Gabb.	×	×	×
Amauropsis alveata Con.	×	×	×
Brachysphingus clarki Wvr.	×	×	
Calyptraea excentrica Gabb.	×	×	×
Crepidula pileum Gabb.		×	×
Cylichna costata Gabb.	×	×	×
Conus hornii Gabb.		×	×
Conus remondii Gabb.		×	×
Exilia dickersoni Wvr.		×	×
Ficus mamillatus Gabb.	×	×	×
Ficopsis cowlitzensis Wvr.	×	×	×
Ficopsis remondi Gabb.		×	×
Galeodea tuberculata Gabb.		×	×
Hemifusus tejonensis Wvr.		×	
Lunatia cowlitzensis Wvr.	×	×	
Mitra washingtoniana Wvr.		×	
Murex sopenahensis Wvr.		×	×
Naticina obliqua Gabb.	×	×	×
Neverita secta Gabb.	×	×	×
Olivella mathewsonii Gabb.		×	×
Polinices hornii Gabb.	×	×	
Pseudoliva volutaeformis Gabb.	×	×	
Rimella simplex Gabb.	×	×	×
Surcula cowlitzensis Wvr.		×	×
Sinum obliquum Gabb.	×	×	
Turris monolifera Cooper.		×	
Turritella uvasana Con.	×	×	×
Urosalpinx hannibali Dick.		×	
Dentalium stramineum Gabb.	×	×	×
Aturia mathewsonii Gabb.		×	

Partial List of Flora Occurring in the Cowlitz Formation and their Occurrence in the Swauk and Eocene Auriferous Gravels of California.

	Olequa.	Chehalis.	Swauk.	Aurif. Gravels.
Acer trilobatum productum Al. Braun		×		
Alnus carpinoides Lesqx.		×?		
Aristolochia crassifolia (Nby.) Cockerell		×?		
Betula aequalis Lesqx.		×		×
Betula heteromorpha Kn.		×		
Calamopsis cf. *danae* Lesqx.	×		×	
Carpinus grandis Nby.		×		
Cornus? impressa Lesqx.	×			
Cinnamomum bendirei Kn.	×		×	
Cinnamomum dilleri Kn.	×		×	
Ficus sordida Lesqx.	×	×		×
Ficus tiliaefolia (Al. Braun) Heer	×			×
Grewia crenata (Unger) Heer		×		
Juglans egregia Lesqx.	×			×
Laurus similis Kn.	×			
Magnolia cf. *californica* Lesqx.	×		×	×
Platanus condoni (Nby) Kn.	×			
Populus lindgreni Heer		×		
Populus zaddachi Lesqx.		×?	×	×
Quercus castaneopsis Lesqx.		×		×?
Salix californica Lesqx.		×		×
Salix varians Göppert	×	×		×
Sequoia gracillima (Lesqx.) Nby.		×		
Ulmus californica Lesqx.		×		×
Sabalites campbelli Nby.	×			

The Puget Series.

In 1888, C. A. White[36] published a brief article in which he listed a newly discovered fauna from the Puget Sound Basin in the state of Washington. For the deposits which yielded the fossils, he used the name "Puget Group." White suggests a correlation with the Tejon group of California, the reason being that the beds on the Dwamish River which had yielded Tejon fossils were considered on structural grounds to be the top of the Puget Group. The geology of the district from which the Puget Group was described had been studied and reported by Bailey Willis in 1888. Willis' work was concerned chiefly with the coal resources, but he gives an outline of the stratigraphy in the Wilkeson coalfield.

[36] *Amer. Jour. Sci.*, Vol. 136 (1888), pp. 443–450.

Upper bony beds	10,000 ft.
Wilkeson Series	
Beds at Carbonado	3,000 ft.
Lower beds	
Total	13,000 ft.

In 1889 White[37] described the fauna of the Puget Group. The list of species with the localities from which they came are as follows:

	Newcastle.	Flett's Creek near Wilkeson, 31 mi. S.E. of Tacoma.	Carbonado, 3 mi. S.W. of Wilkeson.	Green River.	Palace Camp.
Batissa dubia White	×	×			
Batissa newberryi White?	×	×	×		
Cardium (Adacna?) ?					×
Corbicula pugetensis White			×		
Corbicula willisi White		×	×	×	
Cyrena brevidens White					×
Psammobia obscura White			×		
Sanguinolaria? caudata White			×		
Cerithium ?			×		×
Neritina ?					×
Teredo pugetensis White			×		

In White's paper a note by J. S. Newberry states that *Sphenopteris (Asplenium) elongata* Nby., occurs at Carbonado, and *Calamopsis danae* Lesqx., at Flett's Creek and at Carbonado. In 1898 Newberry's[38] "Later Extinct Floras," added two more species to the list namely *Lygodium kaulfussi* Heer which occurs at both Flett's Creek and Carbonado and *Anemia perplexa* which occurs at Carbonado. These are reduced to three species, *Anemia elongata* (Newberry) Knowlton, *Chamaedorea danai* (Lesquereux) Berry, and *Lygodium kaulfussi* Heer. This constitutes the entire authentic flora of the type locality of the Puget Group. The list which Knowlton[39] gives in U. S. Geol. Surv. Bulletin 696, contains

[37] U. S. Geol. Surv., Bull. No. 51 (1889), pp. 49–63.

[38] U. S. Geol. Surv., Mon. No. 35 (1898).

[39] U. S. Geol. Surv., Bull. No. 696 (1919), pp. 783–784.

species not yet reported from the type localities of the Puget Group. In the earlier literature Newberry's interpretation of the Puget Group is likely to cause confusion. He does not list only the plants from White's type localities under the name Puget Group but also applies that name to the Cretaceous deposits of the Straits of Georgia. This is not admissible. In addition he includes in his interpretation of the Puget Group, the beds at Bellingham Bay which may be of Eocene age. W. B. Clark [40] gave a brief discussion of the Puget Group in Eocene correlation papers in 1891. In 1897 a further discussion of the age of the Puget Group appeared in a paper by J. P. Kimball [41] which discussed the physiography of Washington. Kimball found marine "Tejon" beds of Eocene age at Brighton Beach, Lake Washington, and about five miles away from this locality he found the "Puget" beds lying at a steep angle and differing wholly in strike from the beds at Brighton Beach. He concludes that this indicates an unconformity and on that ground places the Puget Group in the Cretaceous.

In the following year Willis [42] published a report on the coal fields of Puget Sound in the 18th Ann. Rept. U. S. G. S. In this paper he examines Kimball's evidence and shows that it is unsafe to argue for an unconformity on structural grounds from outcrops five miles apart. He points out that the type of folding in the region is too irregular to admit of any conclusions as to the structural nature of a contact which is not exposed. Willis stated that the Puget Group is stratigraphically continuous with the marine Miocene, or Tejon. In this paper he divides the Puget Group into local formations. Willis states that the coal bearing rocks of Puget Sound have been designated the Puget Formation, citing C. A. White (U. S. G. S. Bull. 51). White however never used any other designation than "Puget Group." But the term Group is inadmissible in stratigraphy since it already has a recognized meaning in Geology. It seems best to use the word Series here. Willis also states that an examination of the plants collected in 1895 and 1896 from Green River, Washington, enabled Knowlton to report that the lower beds are Eocene, while the upper beds may be Miocene.

[40] U. S. Geol. Surv., Bull. No. 83 (1981).

[41] *Amer. Geol.*, Vol. 19 (1897), pp. 304–322.

[42] U. S. Geol. Surv., 18th Ann. Rept., Pt. 3 (1898), pp. 399–436.

In 1899 the Tacoma folio of the U. S. Geol. Survey was issued by Bailey Willis and G. O. Smith.[43] In this paper the "Puget Formation" was subdivided locally into three formations:

Burnett formation (Barren shales and sandstones)	7,000 ft.
Wilkeson formation (Sandstone)	1,000 ft.
Carbonado formation (The coal-bearing beds)	1,100–2,000 ft.

The names Wilkeson and Carbonado were first used by Willis in 1888 and therefore antedate the name "Puget Group." This makes it clear that the latter name applies to the series and not to any part of it. The name Burnett was first used in the Tacoma folio. It should be stated that the authors occasionally used the name South Prairie formation as the exact equivalent of the Burnett formation and in the same district. A note by F. H. Knowlton in this paper gives information in regard to the stratigraphic ranges of the fossil plants.

In 1912 Weaver [44] stated that the "Puget formation" was composed exclusively of brackish water sediments with intercalated lava flows, and that it extends eastward into the Cascade mountains where it passes unconformably beneath later Miocene and Pliocene lava flows. This formation was thought to be the brackish water equivalent of the marine Tejon.

In 1913 Arnold and Hannibal [45] referred the plant localities at the Carbonado and Wilkeson coal mines to the Olequa formation which they considered to belong to the Tejon series of the Middle Eocene.

The stratigraphy and paleontology of the Puget series have never been worked out in any detail for the complete series. Nevertheless both field geologists and teachers have used the name without discrimination for all plant bearing deposits of western Washington and southwestern British Columbia. It might appear that in the uncertain status of the formation the name should be abandoned altogether. However, it was a name properly proposed and intended to include what would now be called a series rather than a single formation. Inasmuch as most of White's fossils came from

[43] U. S. Geol. Surv., Folio No. 54 (1899).

[44] Wash. Geol. Survey, Bull. No. 15 (1912), p. 12–15.

[45] *Amer. Phil. Soc.*, Vol. 52, No. 212 (1913), p. 571.

the Wilkeson coalfield and as the succession of the strata were first made known there, that area may well be considered as the type locality. Furthermore since it is plain that White used the name for the Eocene group of beds, the name should be restricted to the Eocene series if it appears that Miocene beds or Cretaceous beds ever have been included. It appears to the writers that the name "Puget Group," should be replaced by Puget Series and should be used for the entire Eocene series in the Wilkeson coalfield. At present it is unknown how much of the Eocene system is included in this series and therefore uncertain as to whether the name should cover all the Eocene of Washington. Therefore until proper correlation is made the name should not be used away from the type locality. Obviously the correlation cannot be made until the stratigraphy and paleontology of the type section are worked out in detail.

EOCENE.

Washington.		Oregon.	California.	East Coast Gulf.
Cowlitz	Chehalis Olequa		Upper Tejon.	Jackson.
	Crescent	Arago-Umpqua	Meganos.	Claiborne.
	Bellingham Bay (in part) (continental)		Martinez.	Midway. (in part).

LOWER OLIGOCENE OF WASHINGTON.

Arnold[46] mentioned Oligocene in Washington in 1906. At present there are four principal faunas represented in the Oligocene of southern Washington. The oldest of these is known only at Greece's ranch on the left bank of the Cowlitz River, one half mile below the village of Toledo. The fauna was discovered by Anderson

[46] *Bull. Geol. Soc. Amer.*, Vol. 17 (1906), pp. 453–454. See also U. S. Geol. Surv. Prof. Paper No. 47 (1906), p. 15; *Proc. U. S. Nat. Museum*, No. 1617, Vol. 34 (1908), pp. 365–367; *Jour. Geol.*, Vol. 17 (1909), pp. 509–533.

and Martin, and was described in 1917 by Dickerson.[47] A few more species were added in 1918 by K. E. Van Winkle.[48] No stratigraphy has been worked out in any detail. The more important species are:

Arca washingtoniana Dick.
Astarte perrini Dick.
Cardium lincolnensis Weaver.
Cardita weaveri Dick.
Chama pacifica Dick.
Diplodonta dalli Dick.
Lima bella Dick.
Ostrea lincolnensis Weav.
Paphia landesi Van Winkle.
Psammobia martini Dick.
Solen lincolnensis Weav.
Actaeon parvum Dick.
Cancellaria landesi Van Winkle.
Cerithiopsis fasteni Van Winkle.
Conus ruckmanni Dick.
Epitonium condoni Dall.
Eulima clarki Dick.
Exilia weaveri Dick.
Fasciolaria gabbi Dick.
Fusinus gesteri Dick.
Galeodea dalli Dick.
Hemifusus arnoldi Dick.
Littorina oligocene Dick.
Murex vaughani Dick.
Pseudoliva packardi Van Winkle.
Seraphs andersoni Dick.
Triforis martini Dick.

This fauna is considered to represent the lowest Oligocene. Community of species with the later Oligocene formations shows its connection with them rather than with the Eocene. But the presence of certain Eocene genera, shows that if Oligocene, it is at least very old Oligocene. This fauna is not at all closely related to the true *Molopophorus lincolnensis* fauna.

Presumably next younger than the Greece Ranch is the *Barbatia merriami* fauna described by Miss K. Van Winkle[49] in 1918. The correlation of this fauna is still uncertain. The fauna occurs in the Lower Porter beds of Porter and Oakville, and definitely underlies the Upper Porter beds. It is therefore older than the *Turritella porterensis* zone of Weaver, and is believed to be older than the Lincoln beds also, but has no close correlatives. The faunal list, somewhat meager, is as follows:

Arca (Barbatia) andersoni Van Winkle.
Arca (Barbatia) merriami Van Winkle.
Macrocallista newcombei Van Winkle.
Mytilus buwaldana Van Winkle.
Acmaea clarki Van Winkle.
Acmaea dickersoni Van Winkle.
Acmaea oakvillensis Van Winkle.
Calyptraea filosa Gabb.
Cypraea oakvillensis Van Winkle.
Exilia lincolnensis Weaver.
Nassa newcombei Merriam.
Barnacle sp.

[47] *Proc. Cal. Acad. Sci.*, 4th Ser., Vol. 7 (1917), pp. 157–182.
[48] *Univ. Wash. Pub. Geol.*, Vol. 1, No. 2 (1918), pp. 81–92.
[49] *Univ. Wash. Pub. Geol.*, Vol. 1, No. 2 (1918), pp. 81–92.

The fauna of the *Molopophorus lincolnensis* zone and *Turritella porterensis* zone was described by Weaver.[50] The Lincoln horizon or *Molopophorus lincolnensis* zone, was found at the mouth of Lincoln Creek along the banks of the Chehalis River also on Porter Creek stratigraphically below the Porter horizon or *Turritella Porterensis* zone. The fauna was published by Weaver in 1912 and additions have been made by other workers since that time. A partial list of characteristic species is as follows:

Callocallista arnoldi Weaver.
Cardium lincolnensis Weaver.
Cardium lorenzoanum Arnold.
Chione cathartensis Weaver.
Crassatellites washingtoniana Weaver.
Crenella porterensis Weaver.
Leda uvasana Dickerson.
Leda washingtonensis Weaver.
Macrocallista pittsburgensis Dall.
Malletia chehalisensis Arnold.
Mytilus sammamishensis Weaver.
Ostrea lincolnensis Weaver.
Panope estrellana Conrad.
Pitaria dalli Weaver.
Semele gayi Arnold.
Solen lincolnensis Weaver.

Brachysphingus clarki Weaver.
Drillia chehalisensis Weaver.
Epitonium washingtonensis Weaver.
Exilia dickersoni Weaver.
Fusus hecoxi Arnold.
Hemifusus lincolnensis Clk. & Arn.
Lunatia cowlitzensis Weaver.
Molopophorus lincolnensis Weaver.
Strepsidura oregonensis Dall.
Surcula dickersoni Weaver.
Turris thurstonensis Weaver.
Aturia angustata Conrad.

Many of these species also occur in the Porter horizon, so it is presumed that they are not widely separated in time. This fauna is believed to be the equivalent to the San Emigdio of California.

In the upper beds at Porter, Weaver discovered another fauna. This he called the *Turritella porterensis* zone and supposed it to be slightly younger than the underlying *Molopophorus lincolnensis* zone. The Porter fauna is to be correlated with the San Lorenzo of California. A partial list of the fauna is as follows:

Callocallista arnoldi Weaver.
Cardium lorenzanum Arnold.
Crenella porterensis Weaver.
Malletia chehalisensis Arnold.
Marcia oregonensis Conrad.
Pecten peckhami Gabb.
Phacoides acutilineatus Conrad.
Thracia trapezoides Conrad.
Thyasira bisecta Conrad.
Drillia chehalisensis Weaver.
Exilia lincolnensis Weaver.
Fusus hecoxi Arnold.
Turris packardi Weaver.
Turris thurstonensis Weaver.
Turritella porterensis Weaver.

Aturia angustata Conrad.

[50] Geol. Surv. Wash., Bull. No. 15 (1912), pp. 15–16; *Univ. Wash. Pub. Geol.*, Vol. 1, No. 1 (1916), pp. 4–6; *Proc. Calif. Acad. Sci.*, 4th Ser., Vol. 6, No. 2 (1916), pp. 22–52; Geol. Surv. Wash., Bull. No. 13 (1916), p. 166–168.

In 1913 Arnold and Hannibal [51] referred the beds in Washington to the San Lorenzo formation as follows:

> In Washington the conglomerates of the Cape Flattery section and eastward to Shroud Head; the sandstones and shales overlying the Oligocene basalts and andesites south and west of Port Townsend; the sandstones overlying the lower Astoria basalts west of Port Orchard Sound and forming the lower half of the Bainbridge Island section of the Seattle Monocline; the shales overlying the basal Astoria basalts north and east of Oakville, Porter, and Elma; the lowest Oligocene exposed in the Lincoln Creek section; and a large part of the monocline previously mentioned as occurring west of Winlock including the Winlock, Pe Ell, Holcomb, Skamokawa and upper Nasel River exposures are noteworthy.

Arnold and Hannibal gave a faunal list from the San Lorenzo formation which was considered to be the lowest of the three formations in the Astoria Series. The *Molopophorus lincolnensis* and *Turritella porterensis* zones of Weaver are in general the equivalent of the San Lorenzo formation of Arnold and Hannibal. Weaver [52] in 1916 referred to the Oligocene zones, *Molopophorus lincolnensis* zone, *Turritella porterensis* zone, and *Acila gettysburgensis* zone, to the Clallam formation. Weaver's Clallam formation appears to be identical with the Astoria Series as used by Arnold and Hannibal which included the San Lorenzo, Seattle and Twin River formations. This is not a correct use of the name Clallam formation, for if the name Clallam is to be used it should be restricted to Miocene beds as referred to in 1913 by its founder. Until the Washington formations are better known Weaver thought it best not to apply California formation names to them.

Dickerson [53] in 1917 gave a brief discussion of the Oligocene of southwestern Washington and described some new species from the *Molopophorus lincolnensis* zone.

The general features of the Oligocene of the Pacific Coast were discussed by Clark and Arnold [54] in an article published in 1918. The same year Clark [55] used the term San Lorenzo Series as the equivalent of the Astoria Series as used by Arnold and Hannibal, and as equivalent to Weaver's so-called Clallam formation. It

[51] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), p. 579–582.

[52] *Proc. Calif. Acad. Sci.*, 4th Ser., Vol. 6, No. 2 (1916), pp. 26–27.

[53] *Proc. Calif. Acad. Sci.*, 4th Ser., Vol. 6, No. 6 (1917), pp. 157–170.

[54] *Bull. Geol. Soc. Amer.*, Vol. 29 (1918), pp. 297–308.

[55] *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. 11, No. 2 (1918), p. 55.

seems best however, to use local formation names until the Washington formations are better known.

Blakeley Formation.

In 1912 Weaver [56] named the beds at Restoration Point in Kitsap County opposite Seattle, Washington, the Blakeley formation. These beds he stated consisted of about 8,000 feet of shales and alternating sandstones and shales which are overlain by about 1,000 feet of non-fossiliferous conglomerate. Weaver also stated that the Blakeley beds are also exposed in part at Alki Point, Georgetown, the Newcastle Hills, Cathart, the Quimper Peninsula in Chehalis County and at various points along the Strait of Juan de Fuca. He also thought that a large part of what he called undifferentiated Lower Miocene of Cape Flattery corresponded to the Blakeley. The Blakeley formation was considered as Lower Miocene in age.

Arnold [57] found what he considered as a probable Oligocene fauna on Bainbridge Island in 1906 and Dall [58] in 1909 mentions Oligocene strata at Port Blakeley and Restoration Point opposite Seattle. The same year Reagan [59] in his descriptions of the Clallam formation and of new species of mollusks, referred to the "Gettysburg formation," and at another place to the "Gettysburg Series." In a note referring to the Clallam formation which was at that time considered to be Oligocene-Miocene in age, he states:

> Following Doctor Arnold, it is deemed best to use the above term, as the separation of the two members of the group will have to be made on paleontological grounds, and the writer does not feel that material enough has been collected to make that possible at the present time.

Apparently Reagan did not intend to name a Gettysburg formation but merely referred to the rocks at that locality. For this reason the name Blakeley formation has been used in this paper.

In 1913 Arnold and Hannibal [60] in referring to the Blakeley formation state:

[56] Wash. Geol. Surv. Bull. No. 15 (1912), pp. 16–18.

[57] U. S. Geol. Survey, Prof. Paper No. 47 (1906).

[58] U. S. Geol. Survey, Prof. Paper No. 59 (1909), p. 11, 14.

[59] *Trans. Kans. Acad. Sci.*, Vol. 22 (1909), p. 163; 175; 196.

[60] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), pp. 582–585; 605.

Blakeley formation; this name seems to be intended to cover all the Oligocene-Lower Miocene deposits of the Puget Sound and north coast of Washington. The type-section on Bainbridge Island is the exact equivalent of the Astoria Series as recognized by the writers.

The Seattle and Twin River formations of Arnold and Hannibal's Astoria Series seem to be the equivalent of Weaver's Blakeley formation. The maximum thickness of the Seattle formation was found on Bainbridge and was about 3,000 to 4,000 feet in thickness. The Seattle formation was said to lie conformably upon the San Lorenzo beds at Gettysburg, Bainbridge Island, Lincoln Creek, Nasel River, Nehalem River, Yaquina River, and several other places. They stated that the most fossiliferous exposures of this formation were found in the upper beds of a low dipping monocline that extends from Restoration Point on Bainbridge Island across Admirality inlet to Alki Point, Georgetown, and Columbia City in Seattle and that they reappear east of Lake Washington near the mouth of Coal Creek below Newcastle. Also:

Other exposures are to be found in Washington and on the north coast east of Gettysburg and at the mouth of the Sekiu River, in the uppermost Oligocene beds of the Lincoln Creek section, the beds unconformable beneath the Monterey sandstone south of Elma on Delazine Creek, the lower Nasel river and Ilwaco sections, and the bluffs at Grays River. In Oregon the Astoria section, the beds at Nehalem Harbor, and those about the head of Yaquina Bay are contemporaneous.

These beds were referred to the Seattle formation and the fauna was thought not to be as tropical as in the San Lorenzo formation. The Twin River formation was thought to lie conformably above the Seattle beds between Port Crescent and Pysht River on the north coast of Washington and extending about 3 miles east of Twin River nearly to Pysht Bay where it is faulted against the Monterey Miocene. These beds were thought to be about 2,000 feet thick and were composed of clay-shales and interbedded with occasional thin beds of sandstone. The fauna was considered to be of a boreal type and the formation was named from the locality at which the best collecting was found.

In 1916 Weaver[61] stated that the Blakeley horizon or the beds containing the *Acila gettysburgensis* zone was 8,900 feet thick. He stated that the type section is in the strata which outcrop at the

[61] *Proc. Calif. Acad. Sci.*, 4th Ser., Vol. 6, No. 2 (1916), p. 30.

entrance to the Bremerton Navy Yard and that excellent exposures occur at the south end of Bainbridge Island and on the opposite shore to the south. The lowest strata he stated are exposed at Orchard Point and the highest on the north shores of Blakeley Harbor. Weaver considered these beds to be of Upper Oligocene age. In a later paper the same year Weaver[62] practically followed the former one but also stated that a study of the fauna of the type localities of the Seattle and Twin River localities of Arnold and Hannibal do not indicate sufficient ground for making a separation between the two beds. He also stated that detailed mapping shows that the Seattle and Twin River strata occur on the east and west limbs of a syncline and he was of the opinion that the two formations are identical. Weaver did not desire to use the term San Lorenzo for the Washington Oligocene because the faunas are not well enough known; he preferred to use local names and make direct correlations later. In a later paper Weaver[63] followed practically the same conclusions as in the two former papers.

In 1918 K. Van Winkle[64] mentioned the *Acila gettysburgensis* beds and considered them as Upper Oligocene in age. She suggested that the upper part of the Porter horizon be correlated with the lower part of the *Acila gettysburgensis* zone.

In 1923 Clark and Arnold[65] considered the Blakeley horizon or *Acila gettysburgensis* zone as Lower Miocene or Upper Oligocene in age.

Characteristic species found in the *Acila gettysburgensis* zone according to Weaver are:

Chione vespertina Con.
Marcia oregonensis Con.
Nucula (Acila) gettysburgensis Reagan.
Panope generosa Con.
Phacoides acutilineatus Con.
Solemya ventricosa Con.
Spisula albaria Con.
Tellina oregonensis Con.
Thracia trapezoidea Con.
Thyasira bisecta Con.
Crepidula praerupta Con.
Eudolium petrosum Con.
Miopleiona indurata Con.
Turcicula washingtoniana Dall.
Turritella blakeleyensis Wvr.

A study of the *Acila gettysburgensis* fauna shows that it is older than the Monterey-Temblor, Middle Miocene of California

[62] Proc. Calif. Acad. Sci., 4th Ser., Vol. 6, No. 3 (1916), pp. 44–50.
[63] Wash. Geol. Survey, Bull. No. 13 (1916), pp. 168–169.
[64] *Univ. of Wash. Pub. Geol.*, Vol. 1, No. 2 (1918), p. 78.
[65] *Univ. of Cal. Pub. Bull. Dept. Geol.*, Vol. 14, No. 5 (1923), p. 135.

but certain features are somewhat similar. While later studies may show the Blakeley beds to be younger they are at present considered to be of Upper Oligocene age.

THE TUNNEL POINT BEDS.

In 1898 Dall[66] referred to the beds which occur at and southwest of Tunnel Point, Coos Bay, Oregon, as "The Tunnel Point Beds." Dall stated that these beds were composed of about 1,200 feet of shale and sandstone and that they contain a very sparse fauna. He also stated that the Tunnel Point Beds were apparently conformable upon the Eocene beds but were unconformably overlain by the Empire Miocene beds. The faunal aspect of the Tunnel Point beds suggested Oligocene age to Dall.

In 1909 Dall[67] mentioned the Tunnel Point Beds in Prof. Paper 59. In this paper he stated that the Tunnel Point Beds were about 800 feet thick and that the small fauna found was the same as could be found at Restoration Point on Puget Sound and in the *Aturia* bed at Astoria. Dall found that the Tunnel Point beds were faulted and contorted and dip about 60° to 80° to the east. He stated in this paper that there was some evidence of a fault between the Eocene and Oligocene but no fault was observed. He stated that an unconformity occurred immediately east of the ravine called Goldwasher's Gully, between the Empire and the Oligocene. He stated that there is considerable arenaceous shale which contains foraminifera. He also found *Marcia oregonensis* Conrad, *Nucula conradi* Meek, *Saxidomus* aff. *giganteus* Deshayes.

In 1913 Arnold and Hannibal[68] discussed the Tunnel Point beds. They state that the foraminiferal shales which conformably underlie the Tunnel Point Beds contain a characteristic San Lorenzo fauna and that

> The portion of the Tunnel Point beds which are adjacent to the "foraminiferal shales" represent a sandstone phase of the San Lorenzo.

They thought that the greater part of the type section of the Tunnel Point beds from which Dall gave faunal lists was really Empire

[66] U. S. Geol. Survey, 18th Ann. Rept., Pt. 2 (1898), p. 340.
[67] U. S. Geol. Survey, Prof. Paper No. 59 (1909), pp. 14–15.
[68] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), pp. 602–603.

and had been separated from other Empire beds by faulting. They also stated that an angular unconformity can be found which is marked by *Pholas* borings at the type section of the Tunnel Point beds, and this separates the Oligocene from the Miocene.

In 1922 Howe[69] mentions the Tunnel Point beds in his discussion of the Empire beds. He was of the opinion that the *Pholas* borings mark a contact between the Upper Oligocene *Acila gettysburgensis* zone and the Lower Oligocene with *Acila shumardi*. He also thought that there might be a fault at Goldwasher's gully.

The Oligocene of Northwestern Oregon and Willamette Valley.

In 1896 Diller[70] in a paper on northwestern Oregon stated that fossils found at Pittsburg and on the Nehalem River were assigned to the Oligocene by Dall. The rocks were sandstones and shales. Particles of pumice were often found in the sandstones. Fossils listed by Diller which had been identified by Dall are: *Callista*, *Diplodonta*, *Leda*, *Macoma*, *Mactra*, *Mya praecisa* Gould, *Nucula truncata*, *Solen parallelus* Gabb, *Tellina*, *Cylichna*, *Lunatia*, *Molopophorus*, *Neverita saxea* Conrad (?), *Dentalium*. The fossils usually occurred in concretions according to Diller. One mile beyond Veronia up the Nehalem River, *Pentacrinus* and *Periploma* were also found. At Wilson's Bluff in beds a few hundred feet thick he found *Leda*, *Nucula truncata* Gabb, *Pecten peckhami* Gabb, *Tellina*, *Cylichna*, *Dolium petrosum* Conrad, *Scaphander*, *Dentalium*. Diller also reported Oligocene as occurring at Tillamook and at Short Beach in Clatsop County. Other places where fossils were found and assigned to the Oligocene by Dall were, Scapoose, Clatskanie and Nehalem in Columbia County. Diller also mentions that Oligocene occurs 8 miles northeast of Dallas in Polk County and at Blodgett in Benton County.

In 1898 Dall[71] referred the *Aturia* zone at Astoria to the Oligocene. In 1903 Dall[72] described *Macrocallista pittsburgensis* from the Pittsburg Bluffs which had been collected by Diller and in this

[69] *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. 14, No. 3 (1922), pp. 89–90.
[70] U. S. Geol. Surv., 17th Ann. Rept., Pt. 1 (1895–1896), pp. 456–457.
[71] U. S. Geol. Surv., 18th Ann. Rept., Pt. 2 (1898), opposite p. 334.
[72] *Wag. Free Inst. Sci.*, Vol. 3 (1903), p. 1253.

paper Dall gives the age as Eocene. In Prof. Paper 59 Dall [73] in 1909 described *Molopophorus gabbi* from Pittsburg and again gave the age as Eocene. In this paper Dall states that Oligocene occurs at Astoria. In 1913 Arnold and Hannibal [74] were also of the opinion that Oligocene existed at Astoria. Other places at which San Lorenzo beds occur according to Arnold and Hannibal are:

> In Oregon the Astoria shales south of the Columbia River at Clatskanie, Scapoose, the upper Nehalem Valley, and West Dairy Creek, isolated exposures about the borders of the Willamette Valley at Silverton, McCoy, and overlying the Eocene basalts at Eugene and Springfield, the lowest beds of the westward dipping monocline between Blodgett and Newport, and the steeply dipping section exposed in the seacliffs south of the entrance to Coos Bay between Basendorfs (Miner's Flat) and Tunnel Point should be regarded as contemporaneous. The so-called Pliocene of the Yahates River belongs also to this horizon.

These beds were considered to belong to the San Lorenzo, the lowest formation of their Astoria Series. In 1914 Washburne [75] who made a reconnaissance of northwestern Oregon, was also of the opinion that Oligocene occurred at Astoria below the Miocene. He also thought that Oligocene occurred at Tillamook where Dr. Condon of the University of Oregon had found *Aturia angustata*. Washburne also mentioned Oligocene as occurring at other scattered points in northwestern Oregon. The fossil determinations were made by Dall and the Pittsburg beds were assigned to the Eocene. The beds at Eugene were assigned to the Miocene. The flora found near Eugene was sent to Knowlton who thought the flora to be the same as found in the Bridge Creek flora in the upper Clarno, Eocene, in eastern Oregon. A study of the Bridge Creek flora has been made by Chaney [76] and it has been assigned to the Oligocene. The beds at Eugene appear to be probably of lower Oligocene age. In 1914 Anderson and Martin [77] described some new species from northwestern Oregon. From Pittsburg Bluffs on Nehalem River and from near Clatskanie, Oregon, they found *Agasoma columbianum* Anderson & Martin, *Macrocallista pittsburgensis* Dall, *Molopophorus gabbi* Dall and *Nucula shumardi* Dall.

[73] U. S. Geol. Surv., Prof. Paper No. 59 (1909), p. 45.

[74] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), p. 580.

[75] U. S. Geol. Surv., Bull. 590 (1914).

[76] *Amer. Jour. Sci.*, Vol. 208 (1924), p. 128.

[77] *Proc. Cal. Acad. Sci.*, 4th Ser., Vol. 4 (1914), p. 58, 73, 74, 78.

From 10 miles northwest of Scapoose: *Agasoma acuminatum* Anderson & Martin, *Diplodonta parilis* Conrad, *Nucula conradi* Dall, *Tellina oregonensis* Conrad, *Agasoma oregonense* Anderson & Martin. Near Clatskanie *Molopophorus dalli* Anderson & Martin. These localities were considered as questionably Oligocene or lower Miocene by Anderson and Martin. In 1915 Clark [78] considered the Pittsburg fauna to be Oligocene and gave a faunal list which included the following species; *Leda impressa* Conr., *Macrocallista pittsburgensis* Dall, *Nucula shumardi* Dall, *Panope estrellana* Conr., *Phacoides acutilineatus* Conr., *Spisula ramonensis* Packard, *Solen curtus* Conr., *Solen* n.sp. aff. *parallelus* Gabb, *Tellina oregonensis* Conr., *Thracia condoni* Dall, *Agasoma gravidum* Gabb, *Ancilla fishii* Gabb, *Calyptraea excentrica* Gabb, *Fusus hecoxi* Arnold, *Hemifusus washingtoniana* Weaver, *Molopophorus gabbi* Dall, *Galeodea* aff. *tuberculata* Gabb, *Natica oregonensis* Dall, *Natica reclusiana* Petit, *Turritella porterensis* Weaver. In 1918 Clark [79] in a paper dealing with the San Lorenzo of California, discussed the beds at Astoria and at other points in northwestern Oregon. He was of the opinion that no Oligocene was apparent at Astoria, but considered the beds at Pittsburg Bluffs to be of Oligocene age.

In 1920 Harrison and Eaton [80] in an oil report on western Oregon, divide the Oligocene between Toledo and Newport into three formations. The lowest formation they recognize is the Toledo and they state that the type section is 3 miles south of Toledo, Oregon and is the lowest Oligocene in that vicinity. The formation is 2,800 feet thick and is composed of tuffaceous sandstones and shales and is unfossiliferous. This formation according to Harrison and Eaton may be Eocene in part. Overlying the Toledo is the Yaquina formation which is 2,300 feet in thickness. The lower 1,000 feet is made up of coarse-grained, buff-colored sandstones interbedded with carbonaceous shales. Some thin seams of coal occur in the shales. The upper part of the formation is composed of micaceous, gray standstone which is heavy bedded and fossiliferous. This formation according to Harrison and Eaton extends to the town of Yaquina. The fossils cited are: *Acila*, *Thracia*,

[78] *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. 9 (1915), p. 18.

[79] *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. 11 (1918), p. 56.

[80] *Oregon Bureau Mines and Geol.*, Vol. 3, No. 1 (1920), pp. 6–7, 12–13, 29–30.

Aturia angustata, Phacoides, Spisula. Above the Yaquina, is the formation called the Acila shales. It is so named due to the numerous *Acila shumardi* found in the shales. The thickness of the Acila shales is 2,100 feet. Fish scales are found in the shales. Fossils listed are: *Acila shumardi, Acila gettysburgensis, Agasoma gravidum*, Fish scales. The shales are dense, dark-gray and very fine grained. According to Harrison and Eaton they include the Astoria shales in part. The Acila shales are correlated by them with the San Lorenzo of California. These shales are found in the vicinity of Tillamook, Astoria, Clatskanie, Buxton and Willamina. At least a part of the Astoria beds have been shown by other workers to be Miocene of Monterey-Temblor age. The thickness of the Oligocene according to Harrison and Eaton in the Toledo-Newport section is about 7,000 feet.

In an unpublished thesis in 1922 Howe [81] in his discussion of the Miocene mentions the Oligocene in northwestern Oregon. He was of the opinion that no Oligocene is present at Astoria. He also states that angular unconformities occur between the Miocene sandstone and upper Oligocene shales at ½ mile south of Yaquina head and at Jump Off Joe rock. He also stated that 8 miles south of Yaquina Bay the Acila shales seen between Newport and Yaquina are absent as an unconformity occurs at that place. He suggested that faulting may have had some part in this disappearance but he saw no evidence of faults which would account for it. Howe apparently accepted Harrison and Eaton's divisions of the Oligocene. He listed a few fossils from the different divisions. From the Toledo or Lower Oligocene he lists: *Acila shumardi, Macrocallista pittsburgensis* Dall, *Thracia condoni* Dall, *Perse*, etc. From the Yaquina formation he lists: *Metis rostellites, Thyasira bisecta, Crepidula* n.sp., etc. At another locality in the same formation he lists: *Arca* n. sp., *Macrocallista* n.sp., *Phacoides* cf. *acutilineatus, Spisula* cf. *ramonensis, Cancellaria* n.sp. From the Acila shales he lists: "*Acila*" cf. *muta* Clark, *Eudolium petrosum* Dall, *Spirotropis washingtoniana* Weaver. At another locality *Metis rostellites, Phacoides* cf. *acutilineatus, Solemya* n.sp., *Thyasira bisecta, Agasoma* cf. *acuminatum, Crepidula* n.sp.

[81] Unpublished thesis, Leland Stanford Junior University (1922), pp. 41–42.

The aspect of the faunal list from the Acila shales suggests that it is a mixture of northern and southern forms.

It appears that undoubted Oligocene exists at Pittsburg Bluffs on the Nehalem River, and probably also near Scappoose, Clatskanie and Toledo. These appear to be of Lower Oligocene age and possibly the equivalent of the horizon at San Emigdio canyon of California. The faunal assemblage of the beds at Eugene suggests that they may possibly be of Lower Oligocene age.

Some of the fossils occurring there are:

Diplodonta parilis Conrad.
Marcia oregonensis Conrad.
Nucula (Acila) conradi Meek.
Phacoides acutilineatus Conrad.
Solen curtus Conrad.
Spisula albaria Conrad.
Tellina aragona Dall.
Tellina oregonensis Dall?
Tellina eugenica Dall.
Thyasira bisecta Conrad.
Venus parapodema Dall.
Yoldia condoni Dall.
Yoldia oregona Dall.
Agasoma columbianum Anderson & Martin.
Agasoma gravidum Gabb.
Crepidula ungana Dall.
Epitonium (Arctoscala) condoni Dall.
Epitonium (Arctoscala) oregonense Dall.
Ficus modestus Conrad.
Fusinus oregonensis Conrad.
Natica oregonensis Conrad?
Trochita inornata Gabb.

Flora from near Eugene listed by Knowlton in Washburne's report:

Cinnamomum.
Ficus.
Laurus.
Lastrea (Goniopteris) fischeri Heer.
Juglans.
Populus zaddachi Heer.
Quercus simplex Nby.
Rhus.
Sterculia.
Woodwardia.

OLIGOCENE.

Washington.	Oregon.	California.
Blakeley.	Astoria? (Lower part)	
Porter	Tunnel Point (in part)	San Lorenzo.
Lincoln	Pittsburg Bluffs.	San Emigdio.
Greece Ranch.		

Sooke Formation.

The Sooke formation occurs at a number of points along the southwestern shore of Vancouver Island. The type section of the Sooke appears to be found between Muir and Kirby Creeks a few miles west of Sooke harbor along the beach. These beds dip toward the ocean from an angle of 5° to 10°. The Sooke beds lie unconformably upon old volcanics which are of questionable Jurassic age and are known as the Metchosin Series. In most localities the Sooke formation has a few feet of conglomerate at the base and the remainder of the formation consists mainly of sandstone and a few interbedded conglomerates. Drilling near Kirby has shown the Sooke sediments to be over 1,600 feet in thickness.

The rocks from the Sooke locality were first described by Richardson [82] in 1876–1877. In 1892 Dall and Harris [83] considered the Sooke beds to be Neocene in age. In 1869 Merriam [84] published a faunal list from the Sooke formation and gave a discussion of the probable age from a collection made by C. F. Newcombe. Merriam thought that the Sooke beds were Middle Neocene in age. In 1897 Merriam [85] published descriptions of some new species from the Tertiary of Vancouver Island. In 1898 Dall [86] also correlated the Sooke with the Miocene and stated that the Sooke was "probably later than the Empire or the Astoria Miocene." In 1899 Merriam [87] gave a checklist of the Sooke fauna and republished and figured the Sooke species. Arnold [88] probably following Merriam, referred the Sooke to the Upper Miocene.

In 1912 Clapp [89] discussed the Sooke formation as to its age and correlation. Clapp thought that the beds at Carmanah Point were the equivalent of the series of Tertiary sediments exposed along the south shores of the Straits of San Juan de Fuca. This series

[82] Can. Repts. of Explorations and Surveys (1876–1877), pp. 160–192.

[83] U. S. Geol. Surv., Bull. No. 84 (1892), p. 230.

[84] *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. 2, No. 3, pp. 101–108.

[85] *Nautilus*, Vol. 11, No. 6 (1897), pp. 64–65.

[86] U. S. Geol. Surv., 18th Ann. Rept., Pt. 2 (1898), p. 338.

[87] *Proc. Calif. Acad. Sci.*, 3d Ser., Vol. 1, No. 6 (1899), pp. 175–188.

[88] U. S. Geol. Surv., Prof. Paper No. 47 (1906), p. 10; *Jour. Geol.*, Vol. 17 (1909), opposite p. 535.

[89] Can. Dept. Mines, Geol. Surv. Branch, Mem. 13 (1912), pp. 140–141.

was a part of the so-called Clallam formation of Arnold. In 1913 Arnold and Hannibal [90] placed the Sooke in the Lower Oligocene. They gave a faunal list from the Sooke beds. In 1917 C. H. Clapp [91] published a paper discussing the Sooke in which the Paleontology had been prepared by Weaver. According to Weaver the Sooke is to be correlated with the Clallam Series which occurs on the south shore of the Straits of Juan de Fuca.

In 1918 Clark and Arnold [92] referred the Sooke to the Lower Oligocene. In 1923 Clark and Arnold [93] considered the Sooke to be Upper Oligocene or Lower Miocene in age. They correlated it as being the equivalent of the Blakeley formation or *Acila gettysburgensis* zone of Weaver. According to them typical Blakeley and Sooke faunas interfinger near Carmanah Point. The recent aspect of the Sooke fauna in comparison with the fauna of the adjacent water in that region at the present time is noteworthy as has been pointed out by other workers.

A partial list of species from the Sooke formation is:

Antigona vancouverensis Merriam.
Cardium sookense Clk. & Arn.
Cyrene sookensis Clk. & Arn.
Glycimeris vancouverensis Clk. & Arn.
Modiolus sookensis Clk. & Arn.
Mytilus mathewsoni Gabb.
Ostrea sookensis Clk. & Arn.
Pecten columbianum Clk. & Arn.
Saxidomus newcombei Merriam.
Tellina oregonensis Conrad.
Zirfaea sp.

Acmaea hannibali Clk. & Arn.
Agasoma acuminatum And. & Mart.
Ancilla fishi Gabb.
Antiplanes muirensis Clk. & Arn.
Calyptraea sookensis Clk. & Arn.
Cerithidea newcombei Clk. & Arn.
Crepidula sookensis Clk. & Arn.
Eudolium sp.
Fusus hannibali Clk. & Arn.
Goniobasis sookensis Clk. & Arn.
Littorina sookensis Clk. & Arn.
Molopophorus newcombei Merriam.
Rapana perrini Clk. & Arn.
Searlesia branneri Clk. & Arn.

Terebratalia transversa Sowerby.

Siderastrea vancouverensis Vaughan.

Scutella newcombei Kew.

Balanus.

Desmostylus sookensis Cornwall.

There are reasons for considering the possibility of Lower Miocene age for the Sooke fauna. While there are many Oligocene

[90] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), pp. 575–576.
[91] Can. Dept. Mines and Geol., Ser. 80 (1917), pp. 329–339.
[92] *Bull. Geol. Soc. Amer.*, Vol. 29 (1918), p. 304.
[93] *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. 14 (1923), pp. 125–137.

features there are also a few strong Miocene affinities. In California the corals belonging to the genus *Siderastrea* are unknown before the Miocene. This genus appears to have come from the Caribbean at the close of the Oligocene along with other Caribbean forms, as shown by J. P. Smith [94] to be the case with *Lyropecten*. *Rapana* is an oriental form and is also common in the Lower Miocene of California. Furthermore the type of *Scutella* found in the Lower Miocene of California is similar to those found in the Sooke. It is possible that the Sooke may represent a horizon comparable to the Vaqueros of California and younger than uppermost Oligocene.

The Astoria Beds.

In 1848 the first fossils from the West Coast were described by Conrad,[95] these had been collected at Astoria by J. K. Townsend. No age was assigned to the fossils at that time. The next year Conrad [96] assigned those shells to the Miocene when he described another collection from Astoria made by Dana of the Wilkes Exploring Expedition. Dana [97] also gave a brief description of the rocks at Astoria and mentioned the presence of many sandstone dikes. Later Conrad [98] thought that the Astoria beds were of Eocene age because of the presence of the genus *Aturia*. He considered *Aturia ziczac* of Shark River Eocene of New Jersey to be the same as *A. angustata* which he had described from Astoria. They are different species as was later recognized. Newberry [99] questioned the age determination of the Astoria beds and White [100] thought it probable that both Chico-Tejon and Miocene were present at Astoria. Condon first used the term *Astoria Shales* but this was first published by Cope [101] from Condon's unpublished notes. He states:

> . . . the unpublished notes of Prof. Condon, formerly State Geologist, state that the backbone of the Coast Range consists of argillaceous shales, which contain invertebrate and vertebrate fossils, frequently in concretions. Some of the latter

[94] *Proc. Calif. Acad. Sci.*, 4th Ser., Vol. 9 (1919), p. 161.
[95] *Amer. Jour. Sci.*, 2d Ser., Vol. 5 (1848), pp. 432–433.
[96] U. S. Exploring Expedition, Vol. 10 (1849), appen. pp. 1838–1842.
[97] U. S. Exploring Expedition, Vol. 10 (1849), pp. 654–655.
[98] *Amer. Jour. Conch.*, Vol. 1 (1856), p. 150.
[99] Pac. R. R. Repts., Vol. 6, Pt. 2 (1857), p. 25.
[100] U. S. Geol. Surv. Bull. No. 51 (1889), p. 31.
[101] *Amer. Nat.*, Vol. 14 (1880), p. 457.

are Physoclostous fishes with strongly ctenoid scales. To this formation, Dr. Condon gives the name of *Astoria Shales*. Above this is an extensive Tertiary deposit rich in Mollusca, which is usually interrupted by the central elevations of the mountain axis. Prof. Condon refers this to an Upper Miocene age under the name of the *Solen* beds.

In 1892 Dall [102] referred to the lower portion of the series as the *Aturia* beds and considered them to be Eocene. He used the name Astoria Group to include sandstones and shales but not the *Aturia* beds which he thought were Eocene in age and constituted the lower part of the Series. Later Diller [103] mentions that Oligocene had been recognized by Dall at Astoria but he gave no reason for such recognition. Thus Astoria became the type section for the Oligocene of the West Coast. In 1898 Dall [104] in a correlation table referred the Astoria shale to the Oligocene and the Astoria sandstone to the Miocene. In 1909 Dall [105] published an important paper entitled "The Miocene of Coos Bay and Astoria." In this paper he gave an excellent review of the earlier literature, and described some new species. Several of the species listed from Astoria were thought to be of Oligocene age, but the localities from which they came were not definite. In 1913 Arnold and Hannibal [106] published an important paper in which they propose to use the name "Astoria Series," for the entire Oligocene sequence of the northwest. Under this Series they included the San Lorenzo, Seattle and Twin River formations. Hannibal visited Prof. Condon's collection at the University of Oregon. Arnold and Hannibal were of the opinion that the Astoria Shales mentioned by Dr. Condon were included in the San Lorenzo and Seattle formations of their Astoria Series. In regard to the *Solen* beds, *Aturia* bed and Astoria sandstone they state:

The "*Solen* beds" evidently comprised three things, the Empire sandstone of the Coos Bay district with *Solen sicarius* Gld., the sandstones with *Solen curtus* Conr. at the foot of 19th Street at Astoria, unconformable on the Astoria Series and from the accompanying fauna evidently Monterey, and the basal San Lorenzo tuffs at Smith's quarry near Eugene with *Solen curtus* Conr.

The *Aturia* bed at Astoria lies in the Seattle formation.

[102] U. S. Geol. Surv., Bull. No. 84 (1892), p. 224.

[103] U. S. Geol. Surv., 17th Ann. Rept., Pt. 1 (1892), p. 224.

[104] U. S. Geol. Surv., 18th Ann. Rept., Pt. 2 (1898), opposite p. 334; p. 340.

[105] U. S. Geol. Surv., Prof. Paper No. 59 (1909).

[106] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), pp. 576–584; 602–603.

The term "Astoria sandstone" appears to have been intended to cover Condon's *Solen* Beds at Astoria as well as the sandstones intercalated with the Astoria shales in the steep bluffs behind the town.

Arnold and Hannibal recognized both Oligocene and Miocene at Astoria. They considered the lower beds to belong to the Seattle formation of Oligocene age while the upper beds were considered to be of Monterey Middle Miocene age.

Washburne [107] in 1914 recognized both Oligocene and Miocene at Astoria following the determination of the fossils by Dall. The lower 400 feet or less of the Astoria beds were considered by Washburne to be Oligocene while the upper 1,000 feet or less he considered as of Miocene age. He suggested it might be of Lower Miocene age.

In 1918 Clark,[108] upon visiting the type section at Astoria was of the opinion that the upper sandstones were apparently Lower Miocene in age. He found no fossils in the black shales considered to be Oligocene in age by many writers, which occur below the fossiliferous sandstones. Clark thought it best not to use the term Astoria as a general name for the marine Oligocene of the west coast. He extended the name San Lorenzo Series to include all the marine Oligocene of Oregon, Washington and British Columbia. This term he considered to be synonymous with the term "Astoria Series" as used by Arnold and Hannibal and including the marine Oligocene of Washington referred to the Clallam formation by Weaver. Arnold and Hannibal's term is not used and Clark's extension of the San Lorenzo, a California formation name to the northwest does not seem advisable until the formations of the northwest are better known.

Recently Howe [109] investigated the Astoria locality and states that the two standstones present, one underlying the Astoria shales and one overlying the shales have been confused by several writers. Howe states that by careful mapping the beds containing *Aturia* and the places from which Dall lists his fossils are Middle Miocene of Monterey-Temblor age and not Oligocene as thought by Dall. The sediments which make up the Astoria peninsula according to Howe are a portion of the south limb of "a bent and some-

[107] U. S. Geol. Surv., Bull. No. 590 (1914), p. 15.
[108] *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. 11, No. 2 (1918), p. 55.
[109] Unpublished thesis, Leland Stanford Junior University (1922).

	Astoria Sand-stone.	Astoria Shale.	Lincoln County Miocene.	Calif. Monterey Miocene.	Clallam.
Arca devincta Conrad	×		×	×	×
Diplodonta parilis Conrad	×			×	×
Macoma arctata Conrad	×	×	×	×	
Marcia oregonensis Conrad	×	×	×	×	×
Modiolus rectus Conrad	×		×		×
Nucula (Acila) conradi Meek	×		×	×	×
Nucula (Acila) gettysburgensis Reagan		×			
Panope generosa Gould	×		×	×	
Pecten peckhami Gabb		×		×	
Pecten propatulus Conrad	×	×	×	×	×
Pecten stanfordensis Arnold		×		×	
Phacoides acutilineatus Conrad	×	×	×	×	×
Solen curtus Conrad	×		×	×	×
Spisula albaria Conrad	×		×	×	×
Tellina oregonensis Conrad	×		×	×	×
Thracia trapezoides Conrad	×	×		×	×
Thyasira bisecta Conrad		×		×	×
Venericardia subtenta Conrad	×		×	×	×
Venus ensifera Dall	×		×		
Yoldia impressa Conrad	×		×	?	×
Agasoma oregonensis Conrad	×		×	×	×
Argobuccinum dilleri And. & Mar.	×		×		
Bathytoma condonana And. & Mar.			×	×	
Cancellaria oregonensis Conrad	×		×	×	
Calyptraea inornata Gabb	×		×	×	
Crepidula praerupta Conrad	×		×	×	×
Drillia temblorensis And. & Mar.	×			×	
Eudolium petrosum Conrad	×		×		
Ficus modestus Conrad	×		×	×	
Miopleiona indurata Conrad	×		×		
Nassa andersoni Weaver	×		×		×
Natica reclusiana Petit	×		×	×	
Trophon kernensis Anderson			×	×	
Trophosycon kernianum Cooper			×	×	
Turris medialis Conrad	×		×		
Turritella oregonensis Conrad	×		×		
Aturia angustata Conrad	×	×			×
Dentalium conradi Dall	×	×			×
Terebratalia obsoleta Dall		×			
Terebratulina unguicula Carp.			×		

what irregular syncline." The axes of this syncline were found best exposed east of Astoria near the mouth of John Day River. According to Howe 54 per cent. of the species present in the shales are also present in the sandstones, and 43 per cent. of the species occurring at Astoria are also found in the Monterey-Temblor, Middle Miocene of California. Beds of the same age as those at Astoria have been

mentioned by various writers as present along the northwest coast of Oregon in Lincoln County. The Miocene of Oregon contains such genera which have been shown to be of Asiatic affinity [110] such as, *Eudolium*, *Miopleiona*, *Nucula*. The fauna also shows a mixture of warm water and cool water forms.

A partial list of common species in the Astoria beds is given in this paper, taken in part from Howe shown on opposite page.

Clallam Formation.

The beds around Clallam Bay and Freshwater Bay were thought to be of Oligocene-Miocene age by Arnold in 1904. He gave a generalized section having a thickness of about 3,650 feet made up of shales, sandy conglomerates and sandstones. These beds were coal-bearing in some places. Arnold [111] stated that there was an uplift at the end of the Miocene. In 1906 Arnold [112] made a more extensive study of the beds in the region of Clallam Bay and named them the Clallam formation. This term was used to include the series of conglomerates, sandstones and shales which rested unconformably upon the older rocks of the Olympic Peninsula and were well exposed between Clallam Bay and Pillar Point. He gave the age of the formation as Oligocene-Miocene because it would take intensive work to separate the formation on paleontologic grounds. The beds referred to the Clallam formation were as follows: All pre-Pleistocene deposits along the Juan de Fuca Straits and Freshwater Bay to Cape Flattery except the Eocene basalt and tuffs of Crescent Bay and the Pliocene conglomerate of Clallam Bay-Hoko River region. It also included the greater part of the thick series of conglomerates, sandstones and shales exposed in the promontory of Cape Flattery and the sandstone and shale exposed in the hills south of the Bogachiel River. The thickness of the Clallam formation was given as about 3,650 feet while the Waatch-Neah-Bay section which was thought to be mostly Oligocene-Miocene was given as 15,000 feet in thickness. The lower beds at Cape Flattery were not found in this section due to faulting. Many sandstone dikes were found in the shales. The Clallam

[110] *Proc. Calif. Acad. Sci.*, 4th Ser., Vol. 9, No. 4 (1919); p. 162

[111] U. S. Geol. Surv., Bull. 260 (1904), p. 415.

[112] *Bull. Geol. Soc. Amer.*, Vol. 17 (1906), pp. 451–468.

formation was found to be extremely fossiliferous and five faunas were listed. One list came from the clay in the Oligocene shale. The second from the Oligocene clays and sandstones. The third from the Miocene sandstones. The fourth from near the top of the Clallam formation. The fifth from the mouth of Seku River beds which Arnold considered to be the equivalent of the uppermost strata of the Cape Flattery section. He stated that while some of the horizons could be correlated with the Astoria beds, it was extremely difficult to do likewise with the Alaska or California equivalents. He found no Sooke horizon in the Clallam formation.

In 1909 Reagan [113] in a paper on the Olympic peninsula mentioned the Clallam formation and gave lists of the fauna and described some new species. He also considered the Clallam as Oligocene-Miocene in age. The same year Arnold [114] in a correlation table placed the Clallam beds in the Upper Miocene. In 1910 Reagan [115] stated that the fauna of the Clallam beds was more like that at Astoria than that of the beds of Vancouver Island. In 1912 Weaver [116] divided the Miocene of Washington into three formations, the Blakeley, Wahkiakum and Chehalis. The Blakeley has been discussed elsewhere in this paper. The name Wahkiakum was given to a formation in Wahkiakum County on the north side of the Columbia River near the head of the Alockaman River. This formation is made up of approximately 4,000 feet of mostly sandstones and some shales and grits. It contained a fauna different than the other formations. It lay unconformably upon shales whose horizon was not definitely known but was thought to correspond to the Blakeley. The Wahkiakum fauna appeared to be closely related to the Lower Monterey of California according to Weaver. The name Chehalis was used for the formation occurring in the hills south of the Chehalis River in Chehalis County, Washington. This formation was made up mostly of sandy shales and shaly sandstones about 7,000 feet in thickness. The Chehalis formation according to Weaver lies upon the Blakeley formation and is unconformably overlain by the Upper Miocene. Weaver

[113] *Trans. Kans. Acad. Sci.*, Vol. 22 (1909), pp. 170–198.

[114] *Jour. Geol.*, Vol. 17 (1909), opposite p. 532.

[115] *Centralblatt für Mineral. Geol. und Palaeo.* (1910), p. 651.

[116] Wash. Geol. Survey, Bull. No. 15 (1912), p. 17.

thought the Chehalis formation might be the equivalent of the Upper Monterey of California.

In 1913 Arnold and Hannibal [117] considered the Clallam formation as the equivalent of the Monterey of California and they limited to this formation the following (p. 587):

The conglomerates overlying the San Lorenzo shales at Carmanah Point on Vancouver Island; and in Washington: the Clallam section and the conglomerates unconformable on the Seattle beds between West Clallam and the Hoko River; a small area of Tertiary sandstone faulted into the so-called Cretaceous north of the Hoh River; an area of shales faulted against the Empire formation on the upper Wishkah River; the westward dipping monoclinal section from a few miles west of Elma to North River Junction on the south side of the Chehalis River and equivalent strata south to the Willipa River; and an isolated area beneath the Pliocene basalt on Elocheman River about twelve miles above the Columbia. In Oregon isolated areas lying on the Astoria series or exposed beneath the Pliocene basalt at Mountain Dale, Westport, the foot of 19th Street at Astoria, and the south shore of Tillamook Harbor are of this age as well as a narrow belt of rocks faulted against the Astoria series and extending for several miles up and down the coast west of Newport.

In respect to the Wahkiakum and Chehalis formations Arnold and Hannibal state:

Wahkiakum formation; the Oligocene-Lower Miocene of southwestern Washington. The type-section is Monterey sandstone but many of the fossils listed came from the Astoria beds on Skamokawa and Grays Rivers.

Chehalis formation; the type section is Monterey and Empire, and the fossils listed a mixture of the shale faunas of the two.

In 1916 Weaver [118] placed the Wahkiakum horizon in the Lower Miocene and referred the fauna to the Arca montereyana (should be A. devincta) zone. The name Chehalis is not used by Weaver [119] in later papers for a Miocene formation but concerning his earlier Chehalis Miocene formation he stated that a large portion of the Chehalis is now included within the Wahkiakum and Montesano formations. The name Chehalis had been used by Lawson many years earlier for Eocene beds. According to Weaver the most characteristic species of the Arca montereyana zone (= A. devincta) are: *Antigona olympidea* Reagan, *Arca montereyana* Osmont (should be A. devincta Con), *Chione securis* Shumard, *Diplodonta parilis* Conrad, *Panope*

[117] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), p. 587, 605.

[118] *Univ. Wash. Pub. Geol.*, Vol. 1, No. 1 (1916), pp. 5–6.

[119] *Proc. Calif. Acad. Sci.*, 4th Ser., Vol. 6 (1916), pp. 21, 30–32. Wash. Geol. Survey, Bull. No. 13 (1916), pp. 21–83, 166, 211.

generosa Gould, *Pecten fucanus* Arnold, *Pecten propatulus* Conrad, *Phacoides acutilineatus* Conrad, *Spisula albaria* Conrad, *Tellina arctata* Conrad, *Tellina oregonensis* Conrad, *Venericardia quadrat* Dall, *Crepidula praerupta* Conrad, *Ficus clallamensis* Weaver, *Fusinus stanfordensis* Arnold, *Polinices saxea* Conrad, *Sinum scopulosum* Conrad, *Dentalium conradi* Dall, *Aturia angustata* Conrad. Weaver considered *Chione clallamensis* Reagan and *Chione olympidea* Reagan to be characteristic species of this horizon. In a revised list of Reagan's Clallam fossils by Dall [120] in 1922, these two species are listed in the synonymy respectively under *Antigona olympidea* Reagan and *Chione securis* Shumard.

Weaver also applied the name Clallam formation to his three Oligocene zones, *Molopophorus lincolnensis* zone, *Turritella porterensis* zone and *Acila gettysburgensis* zone. This is inadmissable because the name Clallam had been limited in 1913 by its founder to the beds of Monterey-Temblor age in the northwest. Arnold and Hannibal extended the name Monterey formation to Oregon and Washington and considered the Clallam formation to be the equivalent of the Monterey-Temblor formation of California. It seems advisable to retain the name Clallam formation at present.

EMPIRE FORMATION.

Miocene sandstone at Coos Bay, Oregon, was first mentioned by B. F. Shumard [121] when he described some fossils collected there by J. Evans. Newberry [122] and Condon, Dall and Harris [123] also mention Miocene along the Oregon coast more or less continuously from Cape Blanco to Port Orford. Diller [124] called the Miocene beds at Coos Bay the "Empire beds" in 1895–1896. These beds according to Diller dip 7° to 11° southwest and are sandy in composition. They are limited above and below by unconformities. Dall [125] stated that the Empire beds "Abut unconformably upon the Oligocene beds at Coos Head and against the Eocene at Marsh-

[120] *Amer. Jour. Sci.*, Vol. 204 (1922), pp. 305–310.
[121] *Trans. St. Louis Acad. Sci.*, Vol. 1, No. 2 (1858), pp. 120–123.
[122] Pac. R. R. Repts., Vol. 6, Pt. 2 (1857), p. 59.
[123] U. S. Geol. Surv. Bull. 84 (1892), p. 223.
[124] U. S. Geol. Surv., 17th Ann. Rept., Pt. 1 (1895–1896), p. 469.
[125] U. S. Geol. Surv., 18th Ann. Rept., Pt. 2 (1896–1897), p. 338.

field in the same region." Dall also states that the Empire beds are overlain at one point by the Coos conglomerate. Dall thought that the Empire beds were the equivalent of the Upper part of the Miocene beds at Astoria and in his correlation table he placed the Astoria sandstone above the Monterey Miocene of California and above the Astoria sandstone he placed the Empire formation.

Diller [126] discussed the Empire beds in the Coos Bay Folio. In this folio Diller states that the Miocene of the Coos Bay district is scarcely more than 500 feet in thickness and that it lies unconformably upon the Arago. His description of the Empire shows that the lower part of the beds is composed of sandstone and dark shale while the upper part is whitish shale which resembles shale at Mist Oregon on the Nehalem River and also resembles the Monterey shales of California. In 1902 Dall [127] mentioned the Empire as "Certainly Miocene." In 1909 Dall [128] described the fauna from the Empire beds and of the Pliocene Coos conglomerate. A part of the Empire fauna was secured by Dall from B. H. Camman who had secured the fossils from along the beach where they had fallen from the bluffs. It seems quite probable that some of the species listed by Dall came from the Oligocene beds in the vicinity from which the fossils came.

In 1913 Arnold and Hannibal [129] used the name Empire to include the Montesano formation of Weaver and part of Weaver's Chehalis formation. Also the Mytilus beds at Shoalwater Bay at Willipa Harbor, Washington, the Quinaielt series of Reagan in part, the Quillayute fauna from the Raft River beds, in part the *Solen* beds of Condon and in part the Tunnel Point beds, as well as the Empire beds of Diller and Dall.

In 1922 Howe [130] published a paper on the Empire formation. Howe was of the opinion that the Empire formation is lower Pliocene in age, and that the Coos conglomerate is a part of the Empire beds. He is of the opinion that there is no angular unconformity between the Coos conglomerate and the Empire beds but that they have the same dip.

[126] U. S. Geol. Surv., Folio No. 73 (1901), p. 3.

[127] U. S. Geol. Surv., Bull. 196 (1902), p. 38.

[128] U. S. Geol. Surv., Prof. Paper 59 (1909), p. 59.

[129] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), pp. 589–592, 603.

[130] *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. 14 (1922), pp. 85–114.

There seems to be some difficulty in accepting all of Howe's conclusions. It appears that the Coos Conglomerate is Pliocene and the Pliocene aspect of the fauna pointed out by Howe seems to be due to the Coos conglomerate but not to the fauna from the Empire beds. Several very important species listed by Dall and Arnold and Hannibal as occurring in the Empire beds are not listed by Howe. These species give the fauna a different aspect. Some of these species are unknown outside the Miocene elsewhere. Some of these species listed by others are: *Mytilus middendorffi* Gmelin, *Nucula conradi* Meek, *Ostrea titan* Conrad, *Phacoides acutilineatus* Conrad, *Yoldia impressa* Conrad, *Yoldia oregona* Shumard, *Chrysodomus nodiferous* Conrad. According to Kew, *Scutella blancoensis* Kew occurs only in the Oligocene but it was found by H. Hannibal in the Empire proper. *Dendraster oregonensis* listed by Howe occurs at Fossil Rock in a Pliocene fauna, not in the Empire proper. *Pecten oregonensis* Howe, is very close to *Pecten propatulus* Conrad. Furthermore if the Empire is the subboreal equivalent of the Wildcat formation, it should have giant *Chrysodomus* in abundance but it does not have as many as the Wildcat beds. *Arca trilineata* Conrad is a warm water species and barely reached as far north as the Wildcat beds on Eel River, and therefore would not be expected in such abundance in the same horizon several hundred miles north of the Wildcat formation on Eel River. *Phalium turricula* Dall listed by Howe is probably Oligocene in age. In the collections of the Leland Stanford Junior University, there is a *Phalium turricula* from the San Emigdio fauna along with *Agasoma columbianum* And. & Mart. *Phalium* and *Sistrum* (if *Sistrum* is correctly identified) do not belong to a northern Lower Pliocene fauna, as both appear to be tropical or subtropical genera.

A partial list of characteristic species from the Empire beds is shown on opposite page.

A partial list of the flora in the L. S. J. U. collection, collected by Mr. Harold Hannibal and identified by E. I. Sanborn and others is:

Acer ?.
Alnus ?.
Betula (fragments).
Conifer leaf.
Castanea castaneaefolia (Unger) Knowlton.
Juglans schimperi Lesquereux?
Laurus grandis Lesquereux.

Laurus princeps Heer.
Magnolia cf. *dayana* Cockerell.
Populus polymorpha Newberry.
Quercus convexa Lesquereux.
Quercus elaenoides Lesquereux?.
Quercus furcinervis americana Knowlton.
Rhamnus cf. *mudgei* Lesquereux ?.
Rhus lesquereuxii Knowlton & Cockerell
Salix angusta Al. braun.
Salix varians Göppert. (upper part of leaf).
Sapindus obtusifolius Lesquereux.
Ulmus sp.

	Empire.	Montesano.	Calif. Monterey-Temblor.
Arca trilineata Conrad	×	×	×
Cardium coosense Dall	×	×	
Cardium meekianum Gabb	×	×	
Chione securis Shumard	×	×	×
Diplodonta parilis Conrad	×	×	
Glycimeris grewingki Dall	×	×	
Macoma inquinata Deshayes	×		
Marcia oregonensis Conrad	×	×	×
Modiolus rectus Conrad	×		
Mytilus middendorffi Gmelin	×		×
Nucula conradi Meek	×	×	×
Ostrea titan Conrad	×		×
Paphia staleyi Dall	×	×	
Pecten coosensis Shumard	×	×	
Pecten propatulus Conrad	×	×	×
Phacoides acutilineatus Conrad	×	×	×
Solen sicarius Gould	×	×	
Spisula albaria Conrad	×	×	
Tellina aragona Dall	×	×	
Yoldia impressa Conrad	×		×
Yoldia oregona Shumard	×	×	×
Ampullina oregonensis Dall	×	×	
Antiplanes perversa Gabb	×	×	
Argobuccinum cammani Dall	×	×	
Bathytoma gabbiana Dall	×	×	
Bullia bogachielia Reagan	×	×	
Calyptraea inornata Gabb	×	×	×
Cancellaria oregonensis Dall	×		×
Chrysodomus imperialis Dall	×	×	
Chrysodomus nodiferus Conrad	×		×
Cymatium pacificum Dall	×		
Fusinus oregonensis Dall	×		
Miopleiona oregonensis Dall	×		
Olivella pedroana Conrad	×	×	×
Phalium aequisulcatum Dall	×	×	
Sinum scopulosum Conrad	×	×	×
Dentalium rectius Carpenter	×		
Discinisca oregonensis Dall	×		
Terebratalia occidentalis Dall	×		
Scutella gabbi Remond	×	×	

The fauna of the Empire seems to indicate that it is younger than the Monterey-Temblor of California and probably older than the Santa Margarita-San Pablo of California. It is probably more nearly the equivalent of the Montesano of Washington but the Montesano appears to represent a longer time extending up into the geological column farther than the Empire. Dr. J. P. Smith [131] apparently held the correct opinion concerning the Empire fauna. Probably the Empire fills a place in the Geological column not well represented in the column in California. The Briones is more nearly a suggestion of it than any other beds. Some of the species in the Empire suggest Pliocene but the migration was from the north and due to the slowly cooling climate these reached California later, in the Pliocene.

Montesano Formation.

The Montesano formation was first named by Weaver [132] in 1912. The type section of the Montesano formation occurs in the vicinity of Montesano in Chehalis County, Washington. Weaver stated that the formation covered about 1,000 square miles. It consists in a large part of massive coarse-grained sandstone of a light brown color, and many intercalated lenses of conglomerate and grit. Shales are common in the upper part but are subordinate in the lower part. The thickness was given as about 5,000 feet. The fauna was found to be distinct from the lower Miocene. Weaver also stated that fossiliferous shales and sandstones occur on the west side of the Olympic Mountains in the basin of the Soleduck and Bogachiel Rivers. The fauna was found to be closely related to the sandstone portion of the Montesano formation in Chehalis County. The thickness was given as about 500 feet. No Montesano beds were found in the vicinity of the Straits of Juan de Fuca, the Puget Sound Basin or in the eastern and southern parts of southwestern Washington. The Montesano fauna was found by Weaver to be closely related to the Empire of Oregon and the San Pablo of California. In 1913 Arnold and Hannibal [133] included all Weaver's Montesano under the Empire formation and stated that evidently

[131] *Proc. Calif. Acad. Sci.*, 4th Ser., Vol. 9, No. 4 (1919), p. 157.

[132] Wash. Geol. Surv., Bull. 15 (1912), pp. 20–22.

[133] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), pp. 589–592, 605.

the Montesano was intended as a local name for the Empire sandstone. According to Arnold and Hannibal the Empire also occurs "On the west coast of the Olympic peninsula between Cape Grenville and the mouth of Quinaielt River, between Cape Elizabeth and Raft River, at the mouth of Raft River, and on the Bogachiel River above Mora." They also thought that the Tertiary rocks of Tchow-Un Point, Queen Charlotte Islands represented the same horizon. The Empire according to them included a part of Weaver's Chehalis formation, a part of the Quinaielt of Reagan, the Quillayute (fauna only), Raft River, and a part of the Quinaielt formation of Arnold. They considered the Empire to be Middle Miocene in age.

In 1916 Weaver [134] stated that the Upper Miocene beds lay unconformably upon the older rocks. During the Upper Miocene according to Weaver, there were two embayments in Western Washington. One existed in a part of the Grays Harbor region while the other covered a small area near the mouth of Quillayute River in southwestern Clallam County. According to Weaver about 5,000 feet of sediments accumulated in the Grays Harbor region and about 1,000 feet near the mouth of the Quillayute River. The sediments are for the most part coarse grained brownish sandstones and conglomerates with small amounts of sandy shales and shales. Weaver stated that possibly the fauna at the mouth of Quinaielt River represented a slightly higher horizon. He referred to the faunas in the formation as the *Yoldia strigata* zone and stated that he had earlier referred to this formation as the Montesano formation. In a later paper Weaver [135] mentions that the fauna of the *Yoldia strigata* zone is found in strata which outcrop in the Chehalis valley in the vicinity of Grays Harbor, and at the mouth of the Quinaielt River and in the lower valley of the Quillayute River. In a slightly later paper Weaver [136] states that the Montesano horizon or *Yoldia strigata* zone has a maximum thickness of 5,400 feet. The sediments are folded. The name *Yoldia strigata* zone has been used by Weaver because of the numerous *Yoldia strigata* Dall found in the Montesano beds. Weaver has also stated

[134] *Univ. Wash. Pub. Geol.*, Vol. 1, No. 1 (1916), p. 7, 8.
[135] *Proc. Calif. Acad. Sci.*, 4th Ser., Vol. 6 (1916), pp. 32–33.
[136] Wash. Geol. Surv., Bull. 13 (1916), p. 213.

that he is in favor of using local names for the stratigraphy until more detailed work has been done.

Some of the characteristic fossils found in this horizon according to Weaver are: *Arca trilineata* Conrad, *Cardium meekianum* Gabb, *Macoma astori* Dall, *Mulinia densata* Conrad, *Pecten coosensis* Shumard, *Solen sicarius* Gould, *Siliqua nuttalli* Conrad, *Yoldia strigata* Dall, *Argobuccinum cammani* Dall, *Chrysodomus imperialis* Dall, *Phalium aequisulcatum* Dall, *Sinum scopulosum* Conrad, *Scutella gabbi* Remond.

MIOCENE.

Washington.	Oregon.	California.
Quillayute ? (in part). Montesano	Empire	Santa Margarita.
Clallam	Astoria (at least upper part)	Briones Monterey-Temblor.
Sooke (occurs on Vancouver Island, British Columbia)		Vaqueros

THE QUILLAYUTE FORMATION.

Reagan [137] first named the Quillayute formation in 1909. This formation occurs in the valley of the Quillayute River but the boundaries of the formation were not definitely ascertained. Reagan also stated that this formation was exposed along the Bogachiel River. The Quillayute formation consists of sandstone, bluish-gray shale and conglomerate. Along the coast the Quillayute formation rests unconformably upon the older rocks. Fossils were found in the north bank of the Bogachiel River and in the bluff south of the abandoned channel of Maxfield Creek on the south side of the

[137] *Trans. Kans. Acad. Sci.*, Vol. 22 (1909), pp. 203–226.

Bogachiel River. The age of this formation was considered by Reagan to be questionably lower Pliocene. Reagan gave a list of the fauna and described some new species.

In 1913 Arnold and Hannibal [138] place in their correlation table, the fauna of the Quillayute formation as the equivalent of the Empire formation of Oregon. Weaver [139] in 1916 considered the beds in the lower Quillayute valley to be of Upper Miocene age.

The fossils collected by Reagan from the Quillayute formation were studied by Dall [140] who published a list of the species in 1922. The following species were included in Dall's list;

Cardium coosense Dall.
Cardium corbis Martyn.
Chione staleyi Gabb.
Macoma inquinata Deshayes.
Mactra (Spisula) albaria Conrad.
Mactra (Spisula) arnoldi Dall.
Mactra (?Spisula) precursor Dall.
Mulinia olympica Dall.
Mya intermedia Dall.
Tagelus sp.
Yoldia (Cnesterium) oregona Shumard.
Antiplanes perversa Gabb.
Buccinum? tenebrosum Hancock.
Chrysodomus imperialis Dall.
?Cylichnella alba Brown.
Cymatium (Linatella) pacificum Dall.
Gyrineum mediocre Dall.
Liomesus ? sulculatus Dall.
Lora miona Dall.
Lora sp.
Natica (Cryptonatica) consors Dall.
Nucella (?var.) quillayutea Reagan.
Nucella sp.
Polinices (Lunatia) galianoi Dall.
Purpura foliata Martyn.
Strombiformis washingtoni Reagan.

Reagan also listed:

Scutella sp.
Whale ribs.

The Quillayute fauna appears to be a mixture much the same as the Quinaielt, but the Quillayute suggests that the fauna is slightly lower and more like the Upper Miocene in faunal aspect, and therefore it is probably somewhat lower than the Quinaielt fauna and may be in part of Upper Miocene age.

The Quinaielt Formation.

The Quinaielt formation was named by Arnold [141] in 1906. Arnold stated that the Quinaielt formation is composed of about 2,200 feet of conglomerates and shales and small amounts of sand-

[138] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), opp. p. 604.
[139] *Proc. Calif. Acad. Sci.*, 4th Ser., Vol. 6, No. 2 (1916), p. 32.
[140] *Amer. Jour. Sci.*, Vol. 204 (1922), pp. 305–314.
[141] *Bull. Geol. Soc. Amer.*, Vol. 17 (1906), pp. 465–466.

stone. The greater part of the formation according to him lies in a great syncline between Cape Elizabeth and Cape Grenville and it is in this trough that the Quinaielt River runs to the sea. Both sides of the syncline are limited by a fault and therefore he could not exactly determine the stratigraphic position. The conglomerates at the mouth of Quinaielt River were thought by Arnold to possibly represent the bottom of the formation. He placed the formation in the Lower Pliocene and as contemporaneous with the Purisima of California. Considerable quantities of almost unaltered wood and bark were found in parts of the formation. To the northward at the mouth of Raft River, beds of concretionary sandstone and gray shale were thought to be an equivalent of the Quinaielt formation. Arnold also stated that the territory from Clallam Bay westward to Hoko River has Pliocene sediments. There the Pliocene occurs unconformably upon the upturned and eroded Clallam formation and is mostly conglomerate about 240 feet in thickness. In the conglomerate Miocene fossils were found which were similar to those at Sekiu River. Probably this is only a part of the formation according to Arnold. Species found by Arnold in the Quinaielt formation are:

Leda sp. (short & smooth).
Lima cf. *hamlini* Dall.
Macoma sp.
Mactra sp.
Paphia cf. *staleyi* Gabb.
Pecten hericius Gould.
Solen sicarius Gould.
Thracia trapezoides Conrad.
Yoldia cf. *cooperi* Gabb.

Anachis sp.
Antiplanes perversa Gabb.
Argobuccinum aff. *oregonense* Redfield.
Chrysodomus aff. *tabulatus* Baird.
Cylichna sp.
Epitonium (*Opalia*) *wroblewskii* Moerch.
Margarites sp.
Natica clausa Broderip & Sowerby.
Solariella peramabilis Carpenter.
Thais canaliculata Duclos.
Thais emarginata Deshayes.
Thais lamellosa Gmelin.

Terebratalia cf. *occidentalis* Dall.

In 1909 Reagan[142] followed Arnold concerning the Quinaielt formation. He also referred to a Raft River formation which outcrops on the north side of the mouth of Raft River but he states that Arnold considered it as a part of the Quinaielt formation.

In 1913 Arnold and Hannibal[143] discussed the Pliocene. They

[142] *Trans. Kans. Acad. Sci.*, Vol. 22 (1909), pp. 202–203.
[143] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), p. 592–595.

referred to the latest Miocene or earliest Pliocene of the North Pacific Coast. They recognized as contemporaneous,

> the Scotia section of Eel River Valley, California, the Coos Conglomerate of Coos Bay, Oregon, and the Miocene-Pliocene portion of the Quinaielt formation near Taholah, Washington, with the Miocene-Pliocene beds of the Seven-mile section and exposures on Twelve-mile Creek south of San Francisco, California.

The Merced formation of California is now thought to be early Upper Pliocene. In the correlation table Arnold and Hannibal place Arnold's Quinaielt formation of 1906 partly as the equivalent of the Empire of Oregon and partly as the equivalent of the Coos Conglomerate of Oregon. Reagan's Raft River fauna is also placed as the equivalent of the Empire formation of Oregon.

Weaver [144] was of the opinion that the strata at the mouth of the Quinaielt River are Upper Miocene in age and belong to his Montesano horizon or *Yoldia strigata* zone.

Possibly the fauna of the Quinaielt formation is a mixture although it appears to be Lower Pliocene in aspect as Arnold suggested, equivalent to the Purisima of California.

The Coos Conglomerate.

Diller [145] gave a description of the Coos Conglomerate in 1896. Dall [146] first gave the name Coos Conglomerate to the formation in 1898. A part of Dall's description of the Coos Conglomerate is:

> This formation occurs at Fossil Rock, Coos Bay, Oregon. It consists chiefly of Miocene fossils, small waterworn chert pebbles, sand, and a few fossil forms still found living in the vicinity, cemented into a hard conglomerate, the whole lying upon an eroded surface of the Empire "Astoria" sandstone, with which it agrees in dip. Only fragments of the original deposit remain, the rest having been eroded, though originally some 10 feet thick.

Dall thought this formation to be Pleistocene in age.

This formation was mentioned in the Coos Bay folio by Diller in 1901. In 1909 Dall [147] gave a list of the species from the Coos Conglomerate. He also stated that at no place was the formation more than 30 feet thick. According to Diller an uplift of 200 feet since the deposition of the Coos Conglomerate has exposed the Coos

[144] *Proc. Calif. Acad. Sci.*, 4th Ser., Vol. 6, No. 2 (1916), p. 32.
[145] U. S. Geol. Surv., 17th Ann. Rept., Pt. 1 (1896), pp. 477–478.
[146] U. S. Geol. Surv., 18th Ann. Rept., Pt. 2 (1898), p. 336.
[147] U. S. Geol. Surv., Prof. Paper 59 (1909), pp. 19–20.

Conglomerate to vigorous erosion. The Coos Conglomerate has been covered by about 20 feet of sand and gravel. According to Dall, along the edge of the beach the Coos Conglomerate is only 4 or 5 feet in thickness but thicker at other points. In 1913 Arnold and Hannibal [148] considered the Coos Conglomerate to be the equivalent of the Merced of Miocene-Pliocene age. They gave a partial faunal list from the Coos Conglomerate.

In 1922 Howe [149] discussed the Coos Conglomerate. Howe was of the opinion that the Coos Conglomerate and the Empire were of the same series and that both were lower Pliocene in age. A few of the species from the Coos Conglomerate are: *Cardium corbis* Martyn, *Macoma calcarea* Gmelin, *Macoma nasuta* Conrad, *Pecten caurinus* Gould, *Pholadidea penita* Conrad, *Antiplanes perversa* Gabb, *Argobuccinum oregonense* Redfield, *Astraea inaequalis* Martyn, *Bittium (stylidium) eschritii* Dall, *Chrysodomus imperialis* Dall, *Littorina remondi* Gabb, *Olivella pedroana* Conrad, *Purpura foliata* Martyn, *Thais lamellosa* Gmelin, *Thais precursor* Dall.

The Empire formation has been described elsewhere in this paper. The Coos conglomerate appears to be without doubt Pliocene in age and is apparently the equivalent of the Merced of California as suggested by Arnold and Hannibal.

PLIOCENE.

Washington.	Oregon.	California.	
	Coos Conglomerate	Merced.	
Quenaielt Quillayute (in part)		Wildcat	Purisima.

THE ELK RIVER BEDS.

In 1902 Diller [150] described and named the Elk River beds at the mouth of Elk River, in southern Oregon. Diller published nothing on the fauna except that he stated that Dall had reported

[148] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), pp. 592–595, 603.

[149] *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. 14 (1922), pp. 86–91.

[150] U. S. Geol. Surv., Bull. 196 (1902), p. 31.

his collections to be of Pleistocene age. He gives the following section:

	Gravel	4′–12′
Elk River beds	Shell beds, sands, and some gravel,	7′–75′
	———Unconformity———	
	Pliocene argillaceous sands.	

In 1913 Arnold and Hannibal[151] published a partial list of the fauna of these beds, but included that of the underlying Pliocene argillaceous sands without any information about the zonal distribution of the species. It is therefore impossible to say which species belong to the Elk River beds and which to the Pliocene beds. They considered the beds as of Upper Pliocene age.

In 1916 B. Martin[152] examined this locality. He studied the fauna of the Elk River beds proper and stated that it is of late Pleistocene age comparable to that of the upper San Pedro fauna. He states that the beds lie disconformably on the Pliocene argillaceous sands, the fauna of which is closely related to the Wildcat beds of northern California. It is unfortunate that Martin did not publish faunal lists of these two formations, the faunas of which are so little known. Martin traced the Pliocene formation north of Elk River along the coast and found it to lie unconformably on the Cape Blanco beds of Diller which he correlates with the Empire formation of Middle Miocene age. At Cape Blanco these beds are overlain by a nameless formation 10 feet thick which is nearly equivalent to the Elk River beds. Martin regards them as not exact equivalents, however, because it appears that the latter were deposited during the formation of the coastal plain while the former were deposited after this plain had been formed. This discrimination does not appear entirely trustworthy, however, unsupported as it is by evidence, and it may be that the beds overlying the Cape Blanco beds are the exact equivalents of the Elk River beds.

In 1919 Dr. J. P. Smith[153] listed a fauna from the "raised beach" at Cape Blanco, which is presumably the Elk River beds. He suggests a correlation with the Lower San Pedro because it contains a cold water fauna. Some of the species listed by him are:

[151] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), pp. 595–597.
[152] *Univ. Cal. Pub. Bull. Dept. Geol.*, Vol. 9 (1916), p. 245–250.
[153] *Proc. Calif. Acad. Sci.*, 4th Ser., Vol. 9, No. 4 (1919), p. 138.

Kennerlia grandis Middendorf.
Macoma middendorfi Dall.
Mya truncata Lam.
Pecten caurinus Gould.
Saxidomus giganteus Desh.
Spisula voyi Gabb.
Venericardia ventricosa Gould.

Amphissa corrugata Hinds.
Antiplanes perversa Gabb.
Argobuccinum oregonense Redf.
Bela harpa Dall.
Bela tabulata Carp.
Boreotrophon gracilis Perry.
Boreotrophon stuarti Smith.
Buccinum strigillatum Dall.
Chrysodomus phoeniceus Dall.
Chrysodomus tabulatus Baird.
Epitonium hindsi Carp.
Natica clausa Brod. & Sower.
Purpura foliata Gmelin.
Sipho halibrechtus Dall.
Solariella cidaris Adams.
Trichotropis cancellata Hinds.
Tritonofusus rectirostris Dall.

Saanich Formation.

The name Saanich was first given by Arnold and Hannibal [154] to a Pleistocene raised beach deposit which occurs,

> . . . benching the Oligocene and glacial deposits at Alki Point and Bainbridge Island in Puget Sound, filling glacial depressions at various points north of Victoria on the Saanich Peninsula of Vancouver Island, terracing the length and breadth of the Straits of Georgia, notably the Sucia Islands . . . .

This formation contains numerous mollusks; many of these live in the adjacent waters and others live in the cold Alaskan waters. Some of the species are extinct. This fauna is somewhat similar to the lower San Pedro of California. Arnold and Hannibal tentatively correlated with the Saanich formation the raised beaches at Cape Blanco, Bandon and Newport in Orgeon and Bay Center in Washington. In glacial hollows which overlie the marine deposits there are beds of marl and peat. In these beds are fresh water shells and the species are identical with those now found in adjacent lakes. A partial list of the species found by Arnold and Hannibal are:

Cardium corbis Mart.
Cardium decoratum Grnk.
Macoma calcarea Gmel.
Macoma inquinata Desh.
Mya arenaria Lam.
Mya truncata Lam.
Mytilus edulis Lam.
Paphia staminea Con.
Paphia tenerrima Con.
Pecten hastatus hericius Gld.
Pecten islandicus Mül.
Saxicava arctica Lam.
Saxidomus giganteus Desh.
Schizothaerus nuttalli Con.
Serripes groenlandicus Gmel.

Buccinum percrassum Dall.
Natica clausa Brod. & Sower.
Polinices lewisii Gld.
Thais lamellosa Gmel.

[154] *Proc. Amer. Phil. Soc.*, Vol. 52 (1913), pp. 597–598.

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RELATION OF MOUNTAIN-BUILDING TO IGNEOUS ACTION.[1]

By REGINALD A. DALY.

Read April 25th, 1925.

Introduction.

In school-days we learned that the famous volcanoes are largely, though of course not wholly, concentrated in the mountain chains. Later on we studied igneous action in the broader sense and found the larger bodies of intrusive rock to be even more thoroughly concentrated in the mountain structures. Today I wish to offer the thesis that the genetic connection of orogeny and igneous action is much more intimate and far-reaching than as suggested by those two rules. In fact, mountain-building seems to involve igneous action "at a distance," at great distance, as well as in the orogenic belt itself.

Field evidence shows the dominant condition for igneous action to be the development of breaking tension in the earth's crust. The search for the cause of widespread tension in the crust has been obstructed by the prolonged rule of the classic contraction-theory of mountain-building. According to this theory, the outer shell of the earth is supposed, in general, to be steadily and everywhere charged with horizontally directed, compressive stresses. To be sure, these stresses are assumed to be locally reversed in sign because of the heterogeneity of the earth's crust, and in any case, local tensions would be specially developed in a mountain range just after the orogenic crisis is passed.

[1] Address given during a symposium on Igneous Action at a meeting of the Philosophical Society of America, Philadelphia, April 25, 1925.

On the other hand, the geological map of the world is showing, ever more clearly, that very long belts of the crust, situated far from mountain chains, were subjected to breaking tension during the respective periods when these chains were formed. Of late years geological opinion has become increasingly favorable to the new conception of the mountain-building process, as genetically connected with the migration of crust-blocks of continental dimensions. F. B. Taylor seems to have been the first to publish this idea. Wegener has independently developed the hypothesis to such a point that its root principle represents the most important problem now being discussed by the European geologists.[2] Some of Wegener's assumptions cannot be defended, and some of his arguments are obviously weak; yet many authorities are willing to accept the new working hypothesis as the best yet devised for the explanation of mountain chains. This is not the occasion for a systematic discussion of the Taylor-Wegener hypothesis. On the other hand, I believe it to be well worth while to study the problem of igneous action on the assumption that the main principle of the Taylor-Wegener explanation of mountains is correct. At the same time it seems necessary to phrase the principle in a new form. Allow me the privilege of stating it baldly and without full discussion of the reasons for changes of emphasis or for the physical assumptions involved.

According to the new conception, a mountain chain is due to the deformation of crust-rocks on the downstream side of a huge "continental" block which is sheared over the earth's body. This displacement is generally described as horizontal, but it seems clear that the motion of the block cannot be purely horizontal; if it moves at all, it must *fall*. If mountain chains are formed by moving "continents," then those continents have *slid*. I therefore offer a statement of the general idea in this form: as a working hypothesis, mountain chains are assumed to be the products of gigantic landslides, the sliding "land," in each case, being of continental or subcontinental proportions.

This landslide hypothesis demands drastic, breaking tensions

[2] F. B. Taylor, *Bull. Geol. Soc. America*, Vol. 20, 1910, p. 625; A. Wegener, "Die Entstehung der Kontinente und Ozeane," 3d ed., Braunschweig, 1922, with an English translation, published in London, 1924.

in the crust on the upstream side of each moving "continent." Each belt of tension will be of the same order of length as that of the mountain chain. The chain itself must also be a zone of strong local tensions in the crust, both during and just after the orogenic paroxysm. Thus, on the two sides of the sliding "continent," upstream and downstream, magmatic eruption or igneous action may be expected in special amount.

Clearly, "continental" sliding is impossible unless the earth's crust rests on a substratum of very small, or zero, strength. If such a substratum exists, then we are directly led to the inquiry whether its weakness is also the fundamental condition for igneous action. Both sliding and eruption mean mobility below the visible terranes.

First of all, therefore, we shall consider the grounds for belief in the reality of a true crystalline-solid crust on the earth, with its correlative, a non-crystalline, glassy substratum. Then we shall pass to the relation of orogeny to igneous action, our principal subject.

Reality of the Earth's Crust; Nature of the Substratum.

The fundamental cause of igneous action at the earth's surface is the rise of molten rock, or magma, from the interior. The fluxing gases that emanate from such a magmatic injection are responsible for the long lives of ordinary volcanoes, those with cone and crater. Effervescence of the gas-charged magma is one of the conditions for the outflow of lava at the surface. Gaseous pressure is probably one of the causes for the initial rise of magma from depth. Yet to explain this displacement of magma, something else than gas-tension in depth seems required.

Fifty years ago, many geologists were satisfied with the idea that the earth has a thin, brittle crust, underlain by a world-circling, liquid shell: a universal, highly mobile, magmatic layer. The multiplied proofs of the high rigidity of the earth's material at all depths, down to the depth of at least half the radius, proved the fallacious character of that idea. The reaction of opinion has led to another premature conclusion, namely, that high rigidity necessarily means crystallinity or true solidity for all earth-shells

to indefinite, but great, depth. On the other hand, seismological data show that pressure is the dominant cause of the rigidity of the earth's interior. For the material at and below the depth of a few scores of kilometers, crystallinity is regarded by some recent writers as having nothing to do with the rigidity. In other words, the pendulum of geological thought is beginning to swing back to the assumption of a true crystalline-solid crust, resting on a world-circling shell or substratum of non-crystalline, glassy material. This material is very rigid when tested against stresses of short period and is thus not highly mobile, as imagined by geologists in the middle of the last century. Nevertheless, because the substratum is glassy, its rigidity breaks down under the influence of moderate but prolonged stress-difference, at a rate and to an extent which are not possible in crystalline rock, however hot this rock may be. Thus, the strength of hot glass, or its ability to resist permanent stress-difference, may be very low and may actually be zero.

If this be true, then we may ask if the instinct of the volcanologists of two or three generations ago was not, after all, sound, as they placed the seat of all igneous action in a universal, non-crystalline shell of the earth, a substratum, not far below the surface.

Several lines of evidence converge on the conclusion that the crystalline-solid crust underlying the continental surfaces is of moderate thickness.

Obviously the deduction must square with cosmogony. The best explanation of the earth we have—Chamberlin's tidal-disruption theory, modified by Jeans and Jeffreys—implies a former molten stage for our planet. A former molten stage in its turn implies stratification according to intrinsic density. Hence Lord Kelvin's famous picture of the cooling earth is highly misleading. The globe could not become a mass crystalline to the core, though "honeycombed" with pockets of residual liquid. Kelvin's convective mechanism must have worked, but only to the point of causing the solidification of the earth to a depth of some tens or scores of kilometers. The primitive crust was therefore thin. Beneath it was a thick shell of glass, in which the initial thermal gradient may have been very different from that computed on

Kelvin's hypothesis of the foundering of crust-flakes all the way to the earth's center. Probably the initial crust became somewhat thinner as the isotherms rose into it. The slow heating by radioactivity would work in the same sense. Ultimately, however, the crystallized shell began to thicken again, though very slowly. Even at the end of one billion years this crust must be relatively thin.

Thus our best cosmogony permits us to believe in crust and hot, glassy substratum, if the facts seem to point that way.

The more direct evidences are derived: (1) from the theory of the thermal gradient at the surface; (2) from the degree of completeness of isostatic balance in the earth; (3) from the fact that mountain structures *sink* as they are formed; (4) from the fact that geosynclinal belts underwent enormous lateral shortening when they were folded into mountain structures; and (5) from the warping of the continental surface because of large-scale extrusions of lava upon that surface. In addition (6), we have certain relevant suggestions from seismology.

1. The thermal gradients accurately measured in bore-holes are variable. The average increase of temperature at 23 deep borings in the eastern United States is 1° C. for about 42 meters of descent. The corresponding average for 18 deep borings in central and western Europe is 1° per 32 meters. The gradient in the Rand mines of South Africa is given as 1° per 115 (?) meters; in the deep boring near Carnarvon, Cape Province, as 1° C. per 49 meters.[3] This last value is of special importance, since the Carnarvon bore-hole is the deepest which has yet been sunk in the basement (old pre-Cambrian) granite-gneiss of any continent and then studied with respect to the thermal gradient.

The commonly accepted mean value for the gradient—3° per 100 meters—had been computed from results obtained in sedimentary terranes, which are certainly not isotropic with respect to the conduction of heat and, in addition, are probably loci of exothermic chemical reactions. Hence it is unsafe to assume so rapid an increase of temperature within the dominant gneiss-granite terrane of the continents. Possibly a better mean value for the surface gradient in the pre-Cambrian complexes is 2° per 100 meters.

[3] R. A. Daly, *Amer. Jour. Sci.*, Vol. 5, 1923, p. 350; L. J. Krige and H. Pirow, *Trans. Geol. Soc. South Africa*, June, 1923, p. 50.

Commonly the rate of increase of temperature itself increases with depth, down to the bottoms of the bore-holes. This acceleration may be connected with increasing temperature, for Poole has shown that the thermal conductivity of granite decreases 25 per cent. as its temperature increases from 10° to 517° C.[4] To the depth of a few tens of kilometers, therefore, we are probably safe in extrapolating from a gradient of 2° per 100 meters.

However, if the gradient is due to the cooling of the earth, it must weaken considerably below some such depth as 50 kilometers. Hence the temperature at the depth of 100 kilometers is probably below 2,000°.

Assuming radioactivity to be the leading source of heat in the crust, and assuming also a great age for the earth, Holmes, Adams, and Jeffreys have independently computed the gradients in depth. Their curves show the present temperatures to have the values given in Table I.

TABLE I.

Depth (km.).	Temperature, according to:		
	Holmes.	Adams.	Jeffreys.
0	0° C.	0° C.	0° C.
50	1,088	870	600
100	1,575	1,290	900
150	1,950 ±	1,620	1,075 ±

Each factor entering into these calculations—amount and distribution of radioactivity, the age of the earth, conductivity and diffusivity of the crust, the initial gradient, etc.—is uncertain. Comparatively small changes in the assumed constants would raise considerably Adams's or Jeffreys' values for the temperatures at depths of 50 and more kilometers. It is significant that at least one of these indirect methods of arriving at subsurface temperatures, the method of Holmes, gives a result which seems necessarily to imply a non-crystalline condition for the material at the depth no greater than about 100 kilometers. For from existing data

[4] H. H. Poole, *Phil. Mag.*, Vol. 24, 1912, p. 45; Vol. 27, 1914, p. 75; Vol. 46, 1923, p. 408.

the corresponding pressure can hardly be supposed to compel crystallization of magma at the temperature range of 1,575° to 1,950°.[5]

Without going deeper into this difficult problem, I shall merely state my own conclusion: the observed temperature gradients and the theory of a cooling earth appear to permit belief in a glassy substratum under the continents. Since we lack direct measurements under the oceans, similar evidence for a true crust in those segments of the earth is not yet to be had.

2. The loading of the earth's surface with thick sediments and the correlative unloading elsewhere are accompanied by plastic yielding in depth. This so-called isostatic adjustment is so well advanced that the globe is kept very nearly in fluid equilibrium, except for inequalities close to the surface. Below the depth of about 100 kilometers the pressures in the earth are almost perfectly hydrostatic. Such a condition of balance implies plasticity, and that to a degree which is very difficult to understand if the earth shells below the depth of about 100 kilometers are crystalline. To produce flow in crystalline rock, the crystal-fabric must be broken down. Under the small stresses, which alone could exist during the completion of isostatic adjustment, the required breakdown of the fabric, even at high temperature, seems incredible. This is true even if the process be imagined to be one of progressive recrystallization.

3. When a mountain chain is formed, geosynclinal and other salic masses are folded and rafted together. Hence, in the orogenic belt there is a great thickening of relatively light rocks. Though of such density, the thickening body of deformed rock keeps sinking into the earth as the folding and thrusting continue, so that, when these horizontal displacements have come to an end, the mean surface of the new mountain structure is not much higher than the mean level of the continental surface. The greater, truly mountainous *height* is attained long afterwards.

This initial sinking of the deformed rock-mass must, apparently, be regarded as an isostatic adjustment. Assuming this to be true,

[5] See A. Holmes, *Geol. Mag.*, Vol. 2, 1915, p. 111; L. H. Adams, *Proc. Washington Acad. Sciences*, Vol. 14, 1924, p. 469; H. Jeffreys, "The Earth," Cambridge, Eng., 1924, p. 89. In reading out the values from Jeffreys' curves, allowance was made for an obvious error in drafting Fig. 4 of his book.

then we are forced to conclude that the material displaced in depth has a density which surpasses but little, if at all, the mean density of the mountain structure itself. This can hardly be more than 2.8 to 2.85. The material squeezed out in depth is not likely to be more salic than basalt. Crystallized basalt, or gabbro, at the required depth, would have the density of at least 3.0. Glassy basalt, at the depth of 50–100 kilometers would have the density of 2.8–2.85. Thus sinking of the mountain-built rocks becomes intelligible on the assumption that the isostatic undertow is located in a glassy layer below a crystalline crust.

4. Further, the great lateral shortening of a geosynclinal belt, as it is converted into a mountain range, implies the shearing of a thick rock-layer over the earth's body through distances of scores or hundreds of kilometers. Displacements on such a scale can not be regarded as due merely to relief of elastic strain, which is confined to the moving layer itself. But, whatever be the cause of the horizontal motion of the layer, we must believe this motion to be possible only because the shearing-planes are located in extremely weak material. Here, again, we are compelled to assume this material to be hot glass, for no crystalline fabric is likely to be of such low strength.

5. Certain facts of petrology and dynamical geology find no easy explanation except on the assumption that the earth's crust is comparatively thin and rests on a layer of glassy basalt. Wherever a very great volume of basaltic lava has been poured out on the earth's surface, the crust within the flooded area has notably sunk. Examples are: the Columbia lava field of the Northwestern States; the Keweenawan field of Lake Superior; the field of plateau-eruption in the North Atlantic; the Deccan of India; and the Bushveld complex of the Transvaal. In each of these cases the original eruptive was basaltic and its transfer in depth evidently caused, or accompanied, deep horizontal flow over a very large area. The plasticity in depth is a witness to great weakness for the material then displaced; such weakness can hardly characterize even very hot basalt, if it be crystalline.

Many geologists prefer to assume that lavas are offshoots of isolated magmatic "pockets," or "reservoirs," in the earth's body,

rather than offshoots of a continuous substratum. None of these writers has, however, clearly shown how such local "reservoirs" could be generated, or, if generated, how they could remain liquid long enough to account for the observed petrogenic cycles. Their assumption is due to two erroneous conceptions: first, that molten lavas originally emanate from chamber or layer characterized in situ by fluency or a high degree of liquidity; secondly, that a glassy and therefore eruptible substratum is not compatible with the proved great rigidity of all the outer earth-shells. For reasons which cannot now be detailed, though in part already sketched, neither of these conceptions appears to be sound.

On the other hand, we know of a number of cases where the earth's crust has been tensioned and cracked over areas hundreds of miles long, and everywhere the through-going fissures have emitted basaltic lava. The Newark basalts, from Nova Scotia through Connecticut and New Jersey to Virginia and probably to Georgia, represent a case in point. Almost or quite simultaneously, similar fissure-eruptions occurred in Brazil, Uruguay, and South Africa, and in each region on an enormous scale. The basalts erupted along the 2,000-mile rift from Syria to Southern Africa are so nearly contemporaneous that, there too, the assumption of an eruptible substratum is much more rational than to attribute all these eruptions to local "magmatic pockets."

6. Of great significance is the recent discovery of a pronounced discontinuity under Central Europe at the depth of 50–60 kilometers. A. and S. Mohorovičić gave the first good proof of its existence. Later Gutenberg, using a different method, arrived at essentially the same result.[8] All three investigators base their conclusion on the sharp changes in the speeds of the longitudinal (V_p) and transverse (V_s) seismic waves at the depth of 50–60 kilometers. To illustrate, I shall use the values given me in a letter, dated February 7, 1925, from Dr. Gutenberg. These values are copied into Table II.

[8] A. Mohorovičić, *Jahrb. Meteor. Observat. Zagreb*, 1909; S. Mohorovičić, Gerland's *Beitr. zur Geophysik*, Vol. 14, 1916, p. 187. B. Gutenberg, in Sieberg's "Erdbebendunde," 1923, p. 301; and *Phys. Zeit.*, 1923, p. 296.

TABLE II.

Depth (km.).	V_p (km./sec.).	V_s (km./sec.).
0	5.5–5.6	3.2 ± 0.1
57	< 6.0 ("vermuthlich" 5.7)	3.45 ± 0.1
60	8.0	4.3

From these values, assuming also certain densities, Gutenberg has calculated the elastic constants of the material at three different depths. The rigidity (R) and bulk modulus (K), or the reciprocal of the compressibility so computed are shown in Table III.

TABLE III.

Depth (km.).	Assumed Density (D).	R (dynes/cm².).	K (dynes/cm².).
0	2.8	2.8×10^{11}	4.75×10^{11}
50	2.9	3.4×10^{11}	5.33×10^{11}
60	3.2	6.25×10^{11}	12.0×10^{11}

The velocity of the transverse wave is given by the equation,

$$(V_s)^2 = \frac{R}{D}.$$

The velocity of the longitudinal wave is given by the equation,

$$(V_p)^2 = \frac{K + 4/3R}{D}.$$

The very sudden increase of V_s at 55–60 kilometers may be explained by an increase in R alone, or a decrease in D alone, or by simultaneous changes in both of these quantities. It is practically certain that the increase of the rigidity must be important. If the density suddenly decreases, at the depth considered, by the amount of 5–10 per cent., a part of the acceleration of the wave could be understood. Though we have no direct experimental data on the rigidity of rocks at high temperature and pressure, it is probable that under pressure rock-glass gains in rigidity faster than does the equivalent crystalline rock at the same temperature. On the other hand, the increase of the rigidity alone can hardly account for the increase of speed of the longitudinal wave at the level of discontinuity. In principle we must agree with Gutenberg in assuming a simultaneous increase of the bulk modulus.

Until experiments on the elasticity of rocks and glasses at high temperatures and pressures are made, it is not possible to discern the exact nature of this discontinuity. Probably the discontinuity is not due to a change of state, from crystalline solid to glass. Gutenberg prefers its explanation as a rapid transition of crystalline, salic rock above to crystalline, femic rock (Sima) below. Even if the density of the Sima at this level is 3.0, instead of Gutenberg's value, 3.2, the compressibility of that material is notably less than the compressibility of any known rock with density of 3.0 at ordinary temperature. Evidently, appropriate experiments are called for.

If, as seems probable, Gutenberg's suggestion is correct, we must look deeper in the earth for the transition from crust to substratum. It is worth noting that S. Mohorovičić claims to have found, at the depth of 120 kilometers, a decided change in the rate of change of velocity characterizing the longitudinal wave. The acceleration is less rapid below the 120-kilometer level than in the material above that level.[7] The depth of this transitional level is identical with the depth of the layer of isostatic compensation, as computed by Helmert. However, this result of the study by Mohorovičić needs confirmation, and it can not be regarded as more than suggestive.

Gutenberg goes further and uses the observed dispersion of the main, surface ("Love") waves, set up by an earthquake, as a test for the existence of discontinuities in other continents and under the oceans. The method is new and not yet subject to thorough valuation, but the results may be noted. Gutenberg finds that the approximate depths of the discontinuity under Eurasia, America, and the Atlantic are, respectively, 55, 50, and 25 kilometers.[8]

If his conclusions are confirmed, we shall face another problem: Why is the discontinuity under the Atlantic only half as deep as that under Central Europe?

As yet Gutenberg has found, in the Pacific area, no discontinuity which is comparable with that found under Europe. The reason for this contrast with the sub-Atlantic segment is not apparent.

[7] S. Mohorovičić, Gerland's *Beitr. zur Geophysik*, Vol. 14, 1916, p. 193.

[8] B. Gutenberg, *Phys. Zeit.*, Vol. 25, 1924, p. 5, and Vol. 26, 1925, p. 259; *Zeit. f. Geophysik*, Vol. 1, 1925, p. 94.

Seismology is evidently beginning to throw light on our problem, though at present we can not be sure of the exact nature of the changes in physical constitution that lead to the rapid changes in wave-speeds at depth.

Summary.—A definitive conclusion is not possible, but I think we are justified in assuming a glassy substratum underneath the continents at an average depth which is not less than 40 kilometers nor much greater than 100 kilometers.[9] The thickness of the corresponding, sub-Pacific part of the crust may be somewhat greater; that of the crust under the Atlantic, Arctic, and Indian oceans may be somewhat less.

Let us, then, postulate a glassy substratum and once more review the consequences which are important for the related problems of mountain-building and igneous action.

Because it is crystalline, the relatively cool crust has average rigidity, or instantaneous, elastic resistance to distortion, which is not far from twice that of good granite; its strength, or its ability to resist permanent set under long enduring pressure, is probably a large fraction of that of good granite. On the other hand, the temperature of the substratum at its contact with the crust is not far from 1,200° C., and increases downward for some scores of kilometers. Because the substratum is glassy and under high pressure, it exhibits rigidity considerably higher than that of the crust, but the hot glass may be assumed to have extremely small strength. This assumption is fundamental. It means that with the passage of time the rigidity of the substratum material, when subjected to prolonged stress-difference, breaks down. In other words, the substratum is supposed to be elastico-viscous, acting, under differential pressure, as a quasi-liquid.

In a sense, then, the substratum is regarded as slippery. It offers almost no permanent resistance to the horizontal shifting of overlying crust-blocks; nor to the vertical displacement of crust-blocks which may become wholly immersed in the hot glassy shell.

[9] In 1923 the writer published in Volume 5 of the *American Journal of Science* (page 349) a paper dealing with the present subject. That study led to the view that the thickness of the crust is of the order of 40 kilometers, and thus like that favored by Osmond Fisher and others. Later study has shown this thickness to be probably an underestimate.

THE PROCESS OF MOUNTAIN-BUILDING.

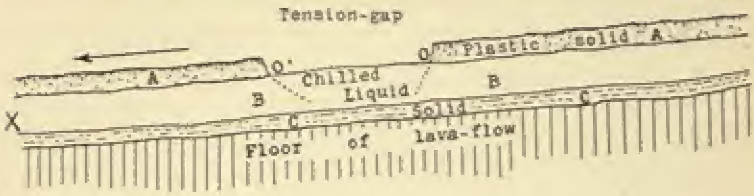
The recognition of these two earth shells, crust and substratum, could hardly fail to have great practical importance for the theories of mountain-building and igneous action. In fact, a mountain chain has been formed by the nearly horizontal shearing of the crust, in its full thickness, over the earth's body, this displacement being accompanied by sinking of great masses of the crust within the folded zone. In this zone the crust has been broken. It is not surprising to find magmatic eruption so specially manifest along such zones.

The pronounced subsidence and even foundering of the rocks in the orogenic belt, as they are folded and rafted together, is possible because the substratum glass is weak and also because it has the low density that goes with the glassy state. Mountainous structures result because the crust *falls* into the plastic body of the earth. The plasticity finds explanation if we assume the existence of the substratum, as described. The same assumption accounts for magmatic intrusion into the roots of the mountains and that on a large scale.

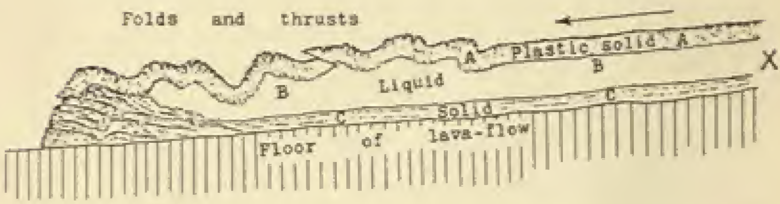
The strong lateral compression of the Alpine and similar geosynclines during mountain-building strongly suggests the other principal condition for orogeny. The compression is much too great to be attributed merely to the release of elastic energy, which had been stored in the crust itself. On the other hand, we can understand the compressional effects if the crust has had energy of position, large blocks of the crust *sliding* toward the geosynclines. This sliding hypothesis can be well illustrated by an analogy.

The accompanying diagram (Fig. 1) represents a longitudinal section of a basaltic lava-flow in Ascension Island. The chilled surface-phase, *A*, because out of level, slid on the liquid-viscous interior, *B*, of the flow. In this way a tension-gap, *O–O′*, was formed upstream, and folds and thrusts were developed downstream, by the weight of the slipping, flexible, solid sheet of rock. The layer *A* is analogous to the warped crust of the earth. The layer *B*, though chilled to rigidity between *O* and *O′*, is analogous to the "slippery" substratum. The downstream belt of deformation is analogous to a mountain chain. The tension-gap is

analogous to those great zones of tension which are typified by the Atlantic basin with its own type of coast-line.



Upstream: Chilled, solid layer, A, slides on hotter, viscous layer, B, which rests on chilled floor-layer, C. Under the tension layer A parts at O. Sliding causes cliffed depression O — O'



Downstream: Folds and thrusts in layer A, caused by its sliding on layer B through the distance O — O'.

FIG. 1. Longitudinal section of a basaltic flow, illustrating development of folds and thrusts downstream, and tension-gap upstream. Section broken at "*X*." The arrows show the direction of flow and of sliding of layer *A* on layer *B*. The liquid of layer *B* was chilled to a condition of rigidity and strength at the tension-gap, as the gap was slowly opened and compelled local, rapid radiation of heat from layer *B*.

In very many basaltic flows, Nature has performed similar "experimental" imitations of mountain-building and the correlative, upstream tearing-apart of the earth's crust.[10]

[10] The remarkable Tertiary folding around the base of the great, complex dome of the Island of Mull needs explanation. Is it possible that this folding was caused by the centrifugal sliding of large fragments of the dome, which had become unstable because of its high elevation, coupled with the weakening of its interior by magmatic injection? The presence of a large body of liquid magma not far below the surface of the dome is suggested by the enormous diking of the region as well as by the widespread pneumatolysis affecting the dome. The strength of such a subterranean body might approach zero; if so, the instability

Time fails for presenting even an outline of the grounds on which this landslide hypothesis is based. Specially important is the difficult question concerning the cause or causes for the distortion of the earth, whereby the crust has been thrown out of level, so far as to slide. I shall now merely offer suggestions without discussion. First, we may well consider the possibility that such broad warping of the crust has depended partly on the contraction of our heterogeneous earth. Other factors may have included secular denudation, and also slow change in the rotational velocity of the globe.

Be it noted, however, that the sliding hypothesis is not necessarily invalidated if the cause of the crustal deleveling can not be demonstrated. One may directly rely on such an observed fact as that a vast stretch of the sub-Pacific crust is now much deeper below sea-level than the remainder; this is shown by Groll's map of the isobaths. Yet more significant is the testimony of paleogeographic maps; imperfect as these may be, they prove crustal warping on a grand scale.[11]

of the dome, originally very high and steep-sided, might be readily conceived. The instability would declare itself in the form of centrifugal sliding, with the generation of breaking tension at the center, while the rocks downstream were folded. That tension was continued long in the central part of the dome is shown by the unmatched assemblage of cone-sheets and ring-dikes, now exposed by erosion. The tentative explanation of the folding, given by the authors of the Mull memoir, is that the thrust was exerted during the central intrusion of granophyric magma. This hypothesis seems inadequate, because the horizontal pressure of this magma could be but little higher than the hydrostatic pressure of the magmatic column, open to the sky. (See the "Tertiary and Post-Tertiary Geology of Mull, Loch Aline, and Oban," Memoir, Geol. Survey of Scotland, 1924, especially Chapter 13.)

Prolonged tension and multiple diking on a scale comparable with those in Mull are observable in Saint Helena Island, where also sliding of a block of an unstable dome seems to have occurred.

F. Reeves (*Amer. Jour. Sci.*, Vol. 8, 1924, p. 310) has considered the possibility of explaining the peripheral folding and thrusting of the strata surrounding the Bearpaw Mountains dome of Montana, by extensive sliding of great blocks of the dome. He describes certain facts which seem to support this hypothesis, but thinks that "the work of deforming the strata was probably too great for such a movement to accomplish."

[11] It should be noted that the deleveling of the crust, caused by the earth's secular contraction or by other processes, does not necessarily imply significant departure of the earth from the isostatic condition.

The potential energy of the deleveled crust would, however, have little importance in mountain-building, if the crust were not underlain by an extremely weak shell of the earth. Such weakness can be expected only on the assumption that the substratum is composed of hot glass. The same assumption furnishes the basis for understanding igneous action in its several phases. In fact, this postulate seems to be the only one that satisfies when the attempt is made to account for the intimate bond between diastrophism and igneous action.

Igneous Action "Upstream."

If colossal landslips crumpled geosynclinal rocks downstream into mountain structures, then upstream the earth's crust must have been under tension both just before and during the folding. Through-going, more or less vertical cracks were developed. Into those cracks the weak material of the substratum was injected, to freeze quickly as dikes. Since the slipping was necessarily slow, many such dikes were formed in succession. Again, in the upstream areas the conditions were favorable for the outpouring of the substratum material on the surface. Hence voluminous fissure or plateau eruptions were also inevitable in these tensioned areas.

We glance at some illustrations. The traps extruded over an immense region, stretching from Franz Joseph Land into Siberia, are contemporaneous with the long-continued deformations of the Tethyan zone, far to the south. The basalts of Greenland, Iceland, and the North Atlantic in general are contemporaneous with the Alpine compression—a long process. Perhaps the basalts of the Newark system were poured out because eastern North America was under the tension which, a little later, was to become stronger during the Jurassic revolution of the Pacific coast. Nearly contemporaneous with the Newark lavas are the basaltic floods of Brazil, Uruguay, and South Africa. The countless dikes associated with these flows seem to show that the Atlantic region as a whole was being slowly stretched. Much greater basaltic floods may be hidden beneath the waters of the relatively young Atlantic basin, such islands as Saint Helena, Ascension, Madeira, and the Canaries being merely the cones built up on a vastly larger volcanic for-

mation. In fact, the suggestion that the sub-Atlantic crust is in part a new crust, composed of erupted basalt, is at least as probable as the older hypothesis that the Atlantic basin is due merely to the post-Paleozoic sinking of salic blocks. No one has yet shown how this second explanation of the basin can be reconciled with that degree of isostatic equilibrium which has been proved for the Atlantic region.

As already implied, the examples given above indicate the nature of the substratum material; it is *basaltic glass*. Fissure-eruptions are rapid, too rapid for pronounced changes in the chemical composition of the erupted glass. On every continent and ocean-floor the comparatively speedy emanations at fissures are all constituted of very hot, glassy basalt. These outflows show us the actual material of the primitive, world-circling substratum.

The landslide hypothesis is supported by that remarkable, major fact, the existence of the Atlantic and Pacific types of coast-line. In both the Old World and the New World, the central Pacific is on the downstream side of the crust-blocks which have slid, and, in sliding, folded and rafted together the rocks downstream; hence the circum-Pacific chains of mountains and the Pacific type of coast-line. The tensions upstream have torn apart the crust along the feet of the continental slopes that surround the Arctic, Atlantic, and Indian ocean basins; hence the Atlantic type of coast-line.

The amount of continental displacement by sliding represents a difficult problem. Wegener considers the migration of continents to be measurable in thousands of kilometers. Since he assumes the continental crust to have been at all times in a state of perfect flotation, he is handicapped when he attempts to show how the shift of continents could have been brought about. This is one reason why his celebrated "drift theory" has not been generally accepted. Nevertheless, many able geologists are regarding the hypothesis of continental migration as eminently worth consideration. Among those sympathetic with the main idea are Staub, Argand, Collet, Kossmat, Schwinner, Ampferer, Molengraaff, du Toit, J. W. Gregory, Cadell, Evans, and Joly. Unfortunately

most American geologists have given the hypothesis scant attention. Among the European geologists opinion varies as to the extent of the migration of continents. In his great memoir, "Der Bau der Alpen," Staub suggests such displacement to the extent of 5,000 kilometers. Kossmat, however, is emphatic in his belief that the shifts have been of very much smaller magnitude.[12] On the present occasion we need not discuss the grounds for this difference of view. Even if we assume any continental block to have slid no more than a few tens of kilometers, we at once obtain a picture of the earth during an orogenic epoch, which is entirely different from the picture given by the classic contraction-theory of the building of mountains.

The first and most essential condition for igneous action is the rise of magma into the earth's crust. In many instances this molten rock appears at the surface, and it is basaltic in composition. That the substratum basalt should occasionally flood the continental surface is to be expected, when a tension-fissure is opened through the whole thickness of the crust. The weight of the crust supplies most of the pressure. Since the density of the bubble-free, basaltic magma filling the fissure is probably very nearly equal to the average density of the continental crust alongside, the bubble-free magma would rise nearly or quite to the earth's surface. Since all primitive basalt effervesces as it rises, its mean density is decreased thereby, as well as by relief of pressure. However, the outflow at the surface is in any case limited, for the crust is far too strong to bend down readily. Long before the crust can bend down to any great extent, the magma has frozen solid in the fissure and closed it. For this and other reasons, which can not here be detailed, the density relations do not imperil the stability of the crust as a whole;

[12] R. Staub, *Beitraege zur geol. Karte der Schweiz*, Lief. 52, 1924, p. 257; F. Kossmat, *Abhand. Sächs. Akad. Wissen., math.-phys. Kl.*, Vol. 38, 1921, p. 42.

It should be noted that F. B. Taylor's conception of continental migration is not identical with the "drift" theory of A. Wegener. Taylor's arguments for such migration are not adequately supported by the presentation of evidence as to the cause of the displacements; yet he has clearly indicated his view that the moving blocks are not in a condition of pure flotation. In this respect the hypothesis of the present writer resembles the conception of Taylor more than that of Wegener, though he differs from both of these authors in picturing the directions and degrees of continental migration.

its general foundering has long been impossible, though, as soon to be noted, local foundering is taken to be one of the leading conditions for mountain-building.

It will be understood also that the pressure effects and fluxing effects of the magmatic gases are by no means to be ignored in the explanation of volcanic action at through-going fissures. In fact, gas-fluxing must be regarded as of prime importance in the mechanism of long-lived, ordinary volcanoes, that is, those with cone and crater. During these few minutes I have time merely to stress the more fundamental cause for volcanic action. Cone and crater, lava flow, dike, sill, and laccolith in tensioned areas can all be well understood as biproducts of deep-seated injections of substratum basalt along more or less vertical fissures through the crust. My main point is that both the fissuring of the crust and the magmatic injection are possible because the substratum is hot glass of almost zero strength, though showing high rigidity to stresses of short periods.

To prevent misapprehension, note should be taken of two special points. This explanation of igneous action applies primarily to the events transpiring since the formation of the basement complexes of the continents. It seems clear that we must think of early pre-Cambrian activity as, for the most part, different in kind and quantity. Secondly, differentiation of the primary basalt and of the products of its interaction with the invaded crust must lead to the formation of intrusive and extrusive rocks which are chemically different from basalt.

Igneous Action "Downstream."

We now turn to the more complex relations in the orogenic belts.

Since late pre-Cambrian time, strong folding and rafting-together of rocks have been confined to geosynclines, major zones of downwarping and sedimentation. The origin of each of these downwarps and its gradual deepening under a load of sediments are problems that still await full solution. The continued existence of geosynclines through long geological periods shows the original crust to have long been out of level. Toward them water ran systematically, bringing its loads of sediment.

As the geosynclinal prism of sediments increases in thickness, the horizontally directed stresses of the deleveled, adjacent crust are also increasing. These pressures are analogous to the horizontal component of pressure exerted at the foot of an artificial dome or a ladder. (See Fig. 2.) When the pressure reaches a certain critical

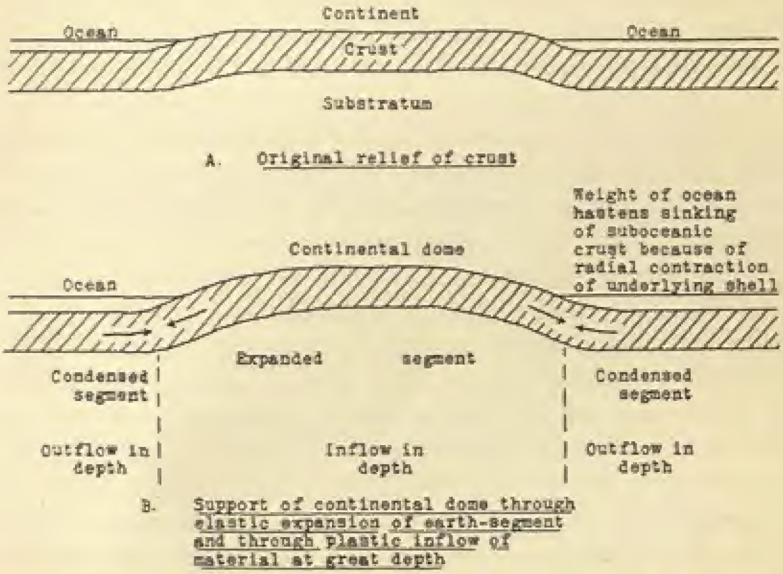


FIG. 2. Sections illustrating distortion of the earth's crust because of the secular contraction of the globe. The crust is here arbitrarily assumed to be uniform in thickness. Principal stresses shown by arrows. These sections relate more specifically to the conditions leading to the development of potential energy which is supposed to have been used in the generation of the circum-Pacific chains of mountains.

value, the crust breaks across at the geosynclinal belt, for this belt is a place of weakness. With the failure of the elastic support of the crustal "dome," new tensions are speedily developed in the central part of the "dome." The "dome" is therefore torn into large blocks, which now proceed to slide toward the geosynclinal belt.

The "slipperiness" of the hot, glassy substratum permits the sliding. Its glassy state also entails another consequence of great importance. The mean density of the suboceanic crust is about 3.0.

The mean density of the upper part of the continental crust is about 2.7. Since the lower part of the continental crust must be more basic, probably crystallized basalt, the density there must be not far from 3.0. The average density of the continental crust is probably 2.80 to 2.85. Allowing for pressure, the density of the upper part of the substratum may be taken as slightly less than 2.85. If a block of the continental crust should sink, so as to be wholly immersed in the substratum, the density of the block would be increased, through compression, by at least .05 and perhaps as much as .1. Hence the block would sink in the substratum. Probably it would not sink many scores of kilometers, because the substratum is itself stratified, its intrinsic density slowly increasing with depth. A block of the suboceanic crust, if immersed, would obviously sink in the substratum.

Now, as the continental block, part of the broken "dome," slides, its downstream, nearly horizontal pressure forces down the crust on one side of the primary fracture in the geosynclinal belt. At equal pace the substratum basalt rises along the fracture, growing rapidly less viscous as it rises to levels of lower hydrostatic pressure. The down-flexed part of the crust, because partly immersed in the less dense substratum, tends to be *pulled* down. When the bending has progressed sufficiently, the downward pull overcomes the bending strength of the crust. Large fragments of the crust are thus broken off, to founder into the substratum. The continuity of the crust is largely destroyed by stoping on a great scale.

In this way the initial elastic resistance to the sliding of the continental fragment is lowered. Further sliding is invited, and now the full pressure at the downstream side of the moving "continent" tends to be concentrated on the light, unsinkable rocks of the geosynclinal prism and its immediate floor. There must also be concentration of the nearly horizontal pressure at successive loci along the geosynclinal belt. With sufficient concentration of pressure, major folding and thrusting, mountain structure, might be expected.

This hypothesis may be illustrated with the aid of Figure 3, a diagrammatic cross-section of a geosynclinal prism and the adjoining part of a large, sliding block of the crust.

The sliding of the "continent" will continue until the remaining gravitational potential becomes too small to break down the elastic and frictional resistance to further sliding. At that stage

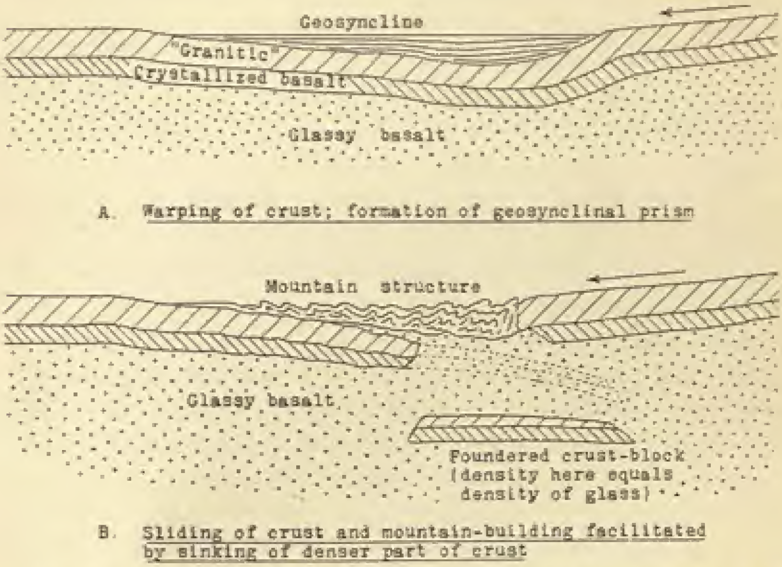


FIG. 3. Sections illustrating: (*A*) the develing of the crust during the formation of a great geosyncline; (*B*) the crumpling of the geosynclinal prism by a "continental" block of the crust, sliding in the direction of the arrow. The arrow of section *A* represents the direction of the growing stress-difference in the crust.

the mountain structure may be described as complete, except for such features as normal faults and the igneous action which must follow the orogenic paroxysm.

The history of igneous action in the mountain belt will obviously be complex. However, three main phases may be distinguished.

1. From the great basaltic wedge, which is injected along the primary fracture at the geosynclinal belt, basaltic magma may be locally extruded at the surface. The earliest eruptive rocks connected with the mountain-building will, then, be basaltic or derivatives of basalt. In the actual mountain chains such early "green rocks" have been found in the positions they should have if they were erupted along the "soles" or listric interfaces

of sliding continents. Suess has emphasized the dynamical significance of such basic eruptives.[13]

2. The downflexed part of the crust and the huge crust-fragments that foundered at the downstream edge of the moving continent are pulled down to levels of high temperature. There they must be both melted and dissolved in the basaltic substratum. Whether melted or dissolved, these more salic rocks will give magmas which are considerably less dense than the glassy basalt. Hence the secondary magmas must rise and invade the roots of the new mountain chain above. There the density relations favor magmatic stoping. This later stoping will be on a relatively small scale, but long-continued, so that an upward penetration of the magma into the mountain structure, through some hundreds or thousands of meters, is possible before the magma freezes solid.

The final results are batholiths and stocks, with their satellitic dikes, sills, laccoliths, chonoliths, and surface volcanics. In general these masses will be of granitic, granodioritic, dioritic, rhyolitic, dacitic, or andesitic nature. Locally, where large bodies of basic sediments are stoped down and assimilated at great depth, the new magmas will have phases which are abnormally low in silica and rich in alkalies. The concentration of the alkalies is largely effected by the resurgent gases, that is, gases which were introduced into the plutonic melts by the abyssal assimilation of sediments. Both resurgent gases and the original, juvenile gases of the erupted basalt are concerned with volcanism at the surface of the mountain structure.

3. Of late years it has become increasingly clear that the great heights of the Tertiary mountains have been attained long after their folding and rafting-together took place. The latter processes resulted in mountain *structure*, but not in notable *height*. In fact, the young mountain ranges of the western Pacific are still largely below sea-level. Broad upwarping, long after folding, has thus characterized the Alps, Himalayas, and the Pacific mountains of the two Americas.

Partial explanation of the late upwarping is at hand, as we realize the true nature of mountain-building. Folding and rafting-

[13] E. Suess, "La Face de la Terre" (translation by E. de Margerie), Paris, Vol. 3, 1918, p. 1497.

together has meant the deep depression of comparatively cool crust-rocks into the earth's body. Very slowly but surely the isotherms have risen into the mountain roots. The inevitable expansion caused the rise of the mountainous surface. Similar expansion of foundered crust-blocks has added to the effect, which was perhaps also controlled in large part by the special radioactivity of salic rocks.

Broad upwarping of the orogenic zone induces tension at and near the surface. Subcrustal expansion must cause tension through the whole thickness of the crust in the folded zone. With the consequent fissuring and rise of gas-charged magma, surface volcanism, both short-lived and long-lived, is to be expected, as a late product of mountain-building. The lavas emitted and the associated intrusives will vary in composition much after the fashion illustrated by batholiths; but typical basalts may ultimately make their appearance at the surface, even in voluminous floods.

This brief deductive account of the magmatic events in a mountain chain seems to be well matched by the history of the North American cordillera.

Summary.

No man liveth to himself. No problem in geology is isolated; it is always tied to other problems, and its ultimate solution hangs on the proper answers to all the other questions of the chain. So it is with igneous action. Neither volcanism nor plutonism can be understood until we understand the formation of mountain chains. This in turn seems to be vitally conditioned by the preliminary distortion of the earth's rocky figure. The bodily distortion, the orogeny, and the igneous action are not to be understood except in the light of a sound theory of the earth's internal constitution and origin. The wise volcanologist must feel compulsion to think on all these things—and many more!

The intimate bond between orogeny and igneous action has been emphasized, and that to a degree not possible until the new hypothesis of continental displacement was imagined. The moving continent is here described as a sliding continent; mountain chains

are explained as structures which have been compressed on the downstream sides of gigantic landslides. The slipping is possible because the crust is underlain by a thick shell of hot, basaltic glass, which, though highly rigid as against stresses of short periods, is extremely weak and therefore "slippery."

The weakness of the glassy substratum is likewise a ruling condition for igneous action. The sliding of a continent occasions breaking tensions in the crust, both upstream and downstream. The through-going fissures so produced are bottomed by the substratum, which loses much of its viscosity by the relief of pressure and nearly all of its rigidity by the sudden development of strong stress-difference. Under the weight of the adjacent crust, these specially mobile fractions of the substratum are forced up into the abyssal fissures. The rise of the magma is aided by gas-pressure, by the effervescence of the magma, and by the contrast of density between the molten rock and the mean crust-rock.

The same contrast of density induces downbending and actual foundering of the crust in the zones of mountain-building. The abyssal heating of these sunken masses generates secondary magmas of the batholithic type. Upstream the dominant magma must be, according to the general hypothesis presented, basalt or its derivatives, though secondary magmas on the small scale may be developed.

Surface volcanism is explained by the rise of primary (basaltic) and secondary magmas into the crust, with the consequent emanation of juvenile and resurgent gases, which act as fluxes in volcanoes of the central type.

Harvard University,
Cambridge, Massachusetts.

MINUTES

MINUTES.

Stated Meeting, January 2, 1925.

Present: Secretary Goodspeed and Professor Ives.

There not being a quorum, no business was transacted.

Stated Meeting, February 6, 1925.

William B. Scott, Sc.D., LL.D., President, in the Chair.

The decease was announced of the following members:

Thomas Corwin Mendenhall, Ph.D., Sc.D., LL.D., at Ravenna, O., on March 23, 1924, æt. 83.

Christopher Stuart Patterson, A.M., at Chestnut Hill, Philadelphia, on November 8, 1924, æt. 82.

Sir Archibald Geikie, O.M., K.C.B., Sc.D., LL.D., at Hashmere, England, on November 11, 1924, æt. 89.

Alden Sampson, A.M., at New York, on January 5, 1925, æt. 71.

John Marshall, M.D., Nat.Sc.D., LL.D., at Philadelphia, on January 21, 1925.

Dr. Charles B. Bazzoni, read a paper on "This Year's Atom," illustrated by lantern slides and discussed by the President.

Stated Meeting, March 6, 1925.

William B. Scott, Sc.D., LL.D., President, in the Chair.

The decease was announced of the following members:

William Francis Hillebrand, Ph.D., at Washington, on February 7, 1925, æt. 72.

Preston Albert Lambert, B.A., at Bethlehem, Pa., on February 15, 1925.

Charles B. Penrose, A.M., Ph.D., M.D., LL.D., at Philadelphia, on February 27, 1925, æt. 63.

Dr. Herbert E. Ives of the Research Laboratories of the Western Electric Company, read a paper on "The Transmission of Photographs by Telephone," which was illustrated by lantern slides and discussed by the President and Dr. Goodspeed.

The Committee on Nominations made its report.

The following resolution offered by Mr. Price on behalf of the Committee on Site, was seconded and adopted by unanimous vote:

Resolved: That the Committee on Site be authorized to employ an Architect to prepare preliminary plans for the proposed new Hall for the Society, the cost to be charged to the Building Fund.

Referring to the recent death of Dr. Penrose, the following resolution presented by Dr. Hays was unanimously adopted:

This Society has heard with deep regret the announcement of the death of Dr. Charles Bingham Penrose and records its high appreciation of his interest in the Society's work, manifested in various ways and finally in the generous contingent bequest to it, contained in his will.

Stated General Meeting, April 23, 24, 25, 1925.

WILLIAM B. SCOTT, Ph.D., Sc.D., LL.D., President, in the Chair.

Professors Albert F. Blakeslee and Charles McL. Andrews, newly elected members, subscribed the Laws and were admitted into the Society.

The decease was announced of the following members:

John F. Hayford, C.E., March 10, 1925, at Chicago, æt. 57.

John Cadwalader, A.B., A.M., LL.D., March 11, 1925, at Philadelphia, æt. 82.

George S. Fullerton, M.A., B.D., LL.D., March 23, 1925, at Poughkeepsie, æt. 65.

James M. Baldwin, M.A., Ph.D., Sc.D., LL.D., æt. 64.

The following papers were read:

"Some Changes in the Composition of the Blood after Hemorrhage," by D. Wright Wilson, Ph.D., Professor of Physiological Chemistry, University of Pennsylvania. (Introduced by Dr. Alexander C. Abbott.)

"The Colloidal Nature of Protoplasm," by William Seifriz, Ph.D., Research Council Fellow. (Introduced by Dr. Henry H. Donaldson.)

"Logic and the Relation of Life to Mechanism," by Edgar A. Singer, Jr., Ph.D., Professor of Philosophy, University of Pennsylvania. (Introduced by Professor W. Romaine Newbold.)

"The Great Chalice of Antioch," by Charles R. Morey, A.M. Professor of Art and Archæology, Princeton University. (Introduced by Professor Walton Brooks McDaniel.)

"The Doctrine of the Bolos in Manichaean Eschatology," by A. V. Williams Jackson, L.H.D., LL.D., Professor of Indo-Iranian Languages, Columbia University.

"New Light on the Origin of the Phoenician Alphabet," by James A. Montgomery, Ph.D., S.T.D., Professor of Hebrew and Aramaic, University of Pennsylvania. (Introduced by Professor George A. Barton.)

"A Neglected Point of View in Colonial History," by Charles M. Andrews, A.M., Ph.D., L.H.D., Professor of American History, Yale University.

"The Character and Ability of Queen Elizabeth," by Edward P. Cheyney, A.M., LL.D., Professor of European History, University of Pennsylvania.

"Railroad Consolidation—Possibilities and Limitations," by Emory R. Johnson, Ph.D., Sc.D., Professor of Transportation and Commerce, University of Pennsylvania.

Friday, April 24th.

Executive Session, 10 o'clock.

William B. Scott, Sc.D., LL.D., President, in the Chair.

The proceedings of the Council were submitted, with the recommendation of fifteen moninees for election this year.

The Council presented the report received by it from the Audit Committee, with the Treasurer's Report. The resolutions appended to the report of the Audit Committee were recommended for adoption and on motion were adopted, as follows:

That the Treasurer be directed to merge into the principal of the General Fund, at the close of each fiscal year, all balances of unexpended appropriations and of unexpended income for that year derived from that Fund.

That the Treasurer be authorized to pay the expense of auditing the Treasurer's Report and the printing of the Report of the Audit Committee as and when certified to him by its Chairman.

The Report of the Finance Committee with its recommendation of appropriations for the year 1926 was unanimously adopted.

Morning Session, 10:30 o'clock

William B. Scott, Ph.D., Sc.D., LL.D., President, in the Chair.

Joseph C. Arthur, Sc.D., LL.D., subscribed the laws and was admitted into the Society.

The following papers were read:

"The Segregation of *Œnothera nanella-brevistylis* from Crosses with *nanella* and with *lamarckiana*," by Bradley M. Davis, A.M., Ph.D., Professor of Botany, University of Michigan.

"The Grass Rusts of South America, Based on the Holway Collections," by Joseph C. Arthur, D.Sc., LL.D., Emeritus Professor of Botany, Purdue University.

"Distribution of Jimson Weeds in South America," by Albert F. Blakeslee, A.M., Ph.D., Resident Investigator in Evolution, Cold Spring Harbor, L. I.

"Notes on the Portuguese Insectivorous Plant *Drosophyllum Lusitanicum*," by John W. Harshberger, A.B., Ph.D., Professor of Botany, University of Pennsylvania.

"A New Interpretation of the Behavior of Self-Sterile Plants," by Edward M. East, M.S., Ph.D., Professor of Experimental Plant Morphology, Harvard University.

"Some Neglected Botanical Results of the Lewis and Clark Expedition," by Rodney H. True, M.S., Ph.D., Professor of Botany, University of Pennsylvania.

"The Subterranean Algal Flora," by George T. Moore, A.M., Ph.D., Director of Missouri Botanical Garden, St. Louis.

"Absorption and Exudation Pressures of Sap in Plants," by Daniel T. MacDougal, Ph.D., LL.D., Director, Department of Botanical Research, Carnegie Institution of Washington.

"The Importance of Field-Work in the Study of Climate," by Robert DeC. Ward, A.M., Professor of Climatology, Harvard University.

"The Relation of the White Man to the Tropics," by Bowman C. Crowell, M.D., Professor of Pathology, Jefferson Medical College. (Introduced by Dr. Albert P. Brubaker.)

Afternoon Session, 2 o'clock.

William B. Scott, Ph.D., Sc.D., LL.D., President, in the Chair.

Dr. Isiah Bowman subscribed the Laws and was admitted into the Society.

The following papers were read:

"On the Electrical Output of the Sun," by Louis A. Bauer, Ph.D., D.Sc., Director of Department of Terrestrial Magnetism, Carnegie Institution of Washington.

"Resolution of Non-Galactic Nebulæ," by Edwin H. Hubble, B.Sc., Ph.D., Astronomer, Mount Wilson Observatory. (Introduced by Dr. John A. Miller.)

"Mars: The Opposition of 1924," by Earl C. Slipher, Astronomer, Lowell Observatory. (Introduced by Dr. John A. Miller.)

"Infra-red Flash and Coronal Spectra of the Eclipse of January 24, 1925," (Sproul Observatory Expedition) by Heber D. Curtis, A. M., Ph.D., Director of Allegheny Observatory, Pittsburgh, and Keivin Burns, Ph.D., Astronomer, Allegheny Observatory.

"Identical Electric Nets in Series," by Arthur E. Kennelly, A.M., Sc.D., Professor of Electrical Engineering, Harvard University.

"Some New Results Obtained through the Extension of the X-ray Laws into the Field of Optics," by Robert A. Millikan, A.B., Ph.D., Sc.D., Director of Norman Bridge Laboratory of Physics, California Institute of Technology, Pasadena, Cal.

"The Application of Automatic Synchronization of X-ray Exposures to the Study of Intra-thoracic Movements," by F. Maurice McPhedran, M.D., of the Henry Phipps Institute, and Charles N. Weyl, B.S., of the Moore School, University of Pennsylvania. (Introduced by Dr. Arthur W. Goodspeed.)

"Some New Experiments in Gravitation," by Charles F. Brush, Ph.D., Sc.D., LL.D., of Cleveland.

"The Soluble Sodium Tungstates," by Edgar Fahs Smith, Sc.D., LL.D., Emeritus Professor of Chemistry, University of Pennsylvamia.

"A Simple Differential Air Thermometer for Use at Low Temperatures," by William A. Noyes, Ph.D., LL.D., Director of Chemical Laboratory, University of Illinois.

"The Analysis of the Smoke Pollution of the Air of a Large City by Means of the Owen Automatic Filter," by George T. Moore, A.M., Ph.D., Director of Missouri Botanical Garden, St. Louis.

The Friday evening lecture was given by Dr. John A. Miller, of Swarthmore, who spoke on "The Total Solar Eclipse of 1926," illustrated by lantern slides.

Saturday, April 25.

Executive Session, 10 o'clock.

William B. Scott, Ph.D., Sc.D., LL.D., President, in the Chair.

Pending nominations for Officers and Members were read and the Society proceeded to an election. The Tellers subsequently reported that the following had been elected:

President.

Charles D. Walcott.

Vice-Presidents.

Henry F. Osborn,
William W. Campbell,
Francis X. Dercum.

Secretaries.

Arthur W. Goodspeed,
John A. Miller.

Curator.

William P. Wilson.

Treasurer.

Eli Kirk Price.

Councillors.

(To serve for 3 years.)
Thomas B. Osborne,
John F. Lewis,
William M. Wheeler,
William Trelease.

Edwin A. Alderman, D.C.L., LL.D., University, Va.
Annie J. Cannon, B.S., Sc.D., Cambridge, Mass.
Arthur Holly Compton, Ph.D., Chicago, Ill.
Charles Day, M.E., Philadelphia, Pa.
William King Gregory, Ph.D., New York City.
William Draper Harkens, Ph.D., Chicago, Ill.
Lewis R. Jones, Ph.D., Sc.D., Madison, Wis.
Elliott Proctor Joslin, Ph.B., M.D., Boston, Mass.
Andrew Cowper Lawsonk Ph.D., Berkeley, Cal.
George Grant McCurdy, Ph.D., New Haven, Conn.
Howard Hawks Mitchell, Ph.D., Philadelphia, Pa.
James Alan Montgomery, Ph.D., S.T.D., Philadelphia, Pa.
Edward Kennard Rand, Ph.D., Cambridge, Mass.
Edgar Arthur Singer, Jr., Ph.D., Philadelphia, Pa.
Joel Stebbins, Ph.D., Madison Wis.

Professor Arthur E. Kennelly presented the following preamble and resolutions, which were fully discussed and on motion referred to the Council with power.

WHEREAS the American Philosophical Society, founded by Benjamin Franklin in 1727, is the oldest learned Society in North America, with an internationally recognized continuous history of scientific achievement, communication and publication in many branches of learning.

WHEREAS the year 1927 will be the Two Hundredth Anniversary of the founding of the Society.

AND WHEREAS the City of Philadelphia is, and long has been, a prominent American Center of Science, Letters, and Learning.

Therefore be it resolved:

(1) That preparations be made to invest the annual meeting of the Society in 1927 with a dignity and public importance worthy of so noteworthy an anniversary in the world's history of learning.

(2) That in order to bring the usefulness of the Society more generally to the notice of the public, the Society's policy should be vigorously supported of holding regular local meetings at monthly intervals as well as national meetings of annual or semiannual frequency.

(3) That in view of the large and widespread increase in the cost of printing and publishing, an appropriate committee be urged to seek for suitable endowment of the Society's publications, in order to maintain their recognized standing as permanent contributions to the knowledge of Mankind.

Morning Session, 10 o'clock

HENRY FAIRFIELD OSBORNE, Ph.D., LL.D., Vice-President, in the Chair.

The following papers were read:

"Recent Explorations in Northern Alaska," by Philip S. Smith, A.M., Ph.D., Geologist, U. S. Geological Survey. (Introduced by Mr. Bryant.)

"The Mounted Skeleton of a New Mesohippus from the Protoceras Beds," by William J. Sinclair, Ph.D., Associate Professor of Geology, Princeton University.

"The Tree of Knowledge, the most ancient known Fossil Forest," by John M. Clarke, Sc.D., LL.D., New York State Geologist and Paleontologist, Albany.

"A Résumé of Researches on the Evolution and Phylogeny of the Proboscidea," by Henry Fairfield Osborn, Ph.D., Sc.D., LL.D., Research Professor of Zoology, Columbia Univ.

"The Reports of the Princeton University Expeditions to Patagonia," by William Berryman Scott, D.Sc., LL.D., Professor of Geology, Princeton University.

"Prehistoric Terminology," by Edwin Swift Balch, A.B., of Philadelphia.

"Ulysses and Nimrod," by Paul Haupt, Ph.D., LL.D., Professor of Semitic Languages, Johns Hopkins University.

Saturday, Afternoon Session, 2 o'clock

WILLIAM B. SCOTT, Ph.D., Sc.D., LL.D., President, in the Chair.

Presentation of a Portrait of Joseph G. Rosengarten, Esq., Vice-President, 1918, by Hampton L. Carson, Esq., on behalf of the donors.

Afternoon Session, 2 o'clock.

WILLIAM B. SCOTT, Ph.D., Sc.D., LL.D., President, in the Chair.

A Portrait of Joseph G. Rosengarten, Esq., by Julian Story was presented to the Society by Hampton L. Carson, Esq., on behalf of Mrs. George A. Saportas and Mrs. Thomas H. Dougherty, Jr.

Mr. George W. Norris of Philadelphia, presented through Dr. Hays, Mr. Duponceau's honorable discharge from the American Army, signed by George Washington.

The Symposium followed, the subject being "Volcanism."

The papers read were:

"The Proximate Causes of Volcanic Phenomena," by Arthur L. Day, Ph.D., Sc.D., Director of Geophysical Laboratory, Carnegie Institution.

"The Relation of Chemical Energy to Volcanism," by Eugene T. Allen, Ph.D., Chemist, Geophysical Laboratory, Carnegie Institution of Washington. (Introduced by President Scott)

"Volcanism from the Standpoint of the Geologist, including Plutonic Intrusions," by Waldemar Lindgren, M.E., D.Sc., Professor of Economic Geology, Mass. Institute of Technology.

"Ultimate Causes of Volcanism as Connected with the Earth's Interior Condition and the Formation of Mountain Ranges," by Reginald A. Daly, A.M., Ph.D., Professor of Geology, Harvard University.

Stated Meeting, November 6, 1925.

CHARLES D. WALCOTT, Sc.D., Ph.D., LL.D., President, in the Chair.

Dr. E. Arthur Singer, a newly elected member, subscribed the Laws and was admitted into the Society.

Acceptances of membership were received from Dr. Edwin A.

Alderman, Dr. Annie J. Cannon, Dr. Arthur H. Compton, Charles Day, Esq., Dr. William King Gregory, Prof. William D. Harkins, Dr. Lewis R. Jones, Dr. Elliott P. Joslin, Prof. Andrew C. Lawson, Prof. George G. MacCurdy, Prof. Howard H. Mitchell, Prof. James A. Montgomery, Prof. Edward K. Rand, Prof. Edgar A. Singer and Prof. Joel Stebbins.

The decease was announced of the following members:

Herman V. Hilprecht, Ph.D., D.D., LL.D., at Philadelphia, March 19, 1925, æt. 66.

John Mason Clarke, Ph.D., LL.D., at New York, May 29, 1925, æt. 19, 1925.

I. Minis Hays, A.M., M.D., at Philadelphia, June 5, 1925, æt. 77.

Mansfield Merriman, Ph.D., Sc.D., LL.D., at Washington, June 24, 1925, æt. 62.

George Gray, A.M., LL.D., at Wilmington, August 7, 1925, æt. 85.

William Curtis Farabee, A.M., Ph.D., at Washington, June 24, 1925, æt. 60.

Charles Frederick Chandler, A.M., Ph.D., LL.D., at New York, æt. 88.

Albert T. Clay, M.A., Ph.D., LL.D., at New Haven, September 14, 1925, æt. 59.

Francis Darwin, Kt., M.A., Sc.D., LL.D., Ph.D., at Cambridge, England, September 19, 1925, æt. 77.

Dr. Goodspeed moved the following resolution which was unanimously adopted:

Resolved, that it is with deep sorrow and sincere regret that the members of this Society have heard of the death of Dr. I. Minis Hays. He gave his time freely and untiringly to the interests and advancement of the Society.

His keen judgment and strict integrity earned for him the respect and esteem of his fellow members. The Society wishes to record its high appreciation of his untiring efforts in behalf of the Society and in the generous contingent bequest to it, contained in his will.

Further Resolved, that this resolution be entered in the minutes of the meeting and a copy sent to the family of Dr. Hays to whom this Society extends its heartfelt sympathy.

Professor Edwin G. Conklin of Princeton University, read a

paper on "Some Modern Aspects of Evolution," which was illustrated by lantern slides and discussed by Dr. McClung.

Stated Meeting, December 4, 1925.

FRANCIS X. DERCUM, A.M., M.D., Ph.D., Vice-President in the Chair.

Dr. Annie Cannon, Dr. Howard Mitchell, Dr. James Montgomery and Charles Day, Esq., subscribed the laws and were admitted into the Society.

Dr. Annie J. Cannon read a paper on "Starlight and its Message," which was illustrated by lantern slides and discussed by Dr. Goodspeed and Professor Snyder.

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